National Research Council Canada
Conseil national de recherches Canada

Division of Energy
Division de l'énergie

Heat Pump Program
Programme des pompes de chaleur

Industrial Application of Heat Pumps

Raymond Landry
Brunswick Mining and Smelting Corporation Limited

March 1985

Canada

NRCC No. 25268

86-04301/

This report summarizes work carried out under contract to the Division of Energy, National Research Council of Canada. It has been published in accordance with the policy of the National Research Council of Canada of making information on energy research and development available to all interested groups. Publication by the National Research Council of Canada does not signify that the contents necessarily reflect the views or policies of the National Research Council of Canada, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. Furthermore, no warranty or representation is made with respect to the accuracy or completeness of the information contained in this report. This report is reproduced here from camera-ready copy prepared by the contractor. The abstract was translated by the National Research Council of Canada.

Le présent rapport constitue un résumé des travaux effectués à contrat par la Division de l'énergie, Conseil national de recherches du Canada (CNRC). Sa publication est conforme à la politique du CNRC qui est de diffuser l'information disponible sur la recherche et le développement énergétiques auprès de tous les groupes intéressés. Son contenu n'exprime pas nécessairement les opinions ou politiques du Conseil national de recherches du Canada et la mention de marques ou produits commerciaux ne doit pas être considérée comme une approbation ou une recommandation d'utilisation. De plus, aucune garantie ni représentation ne peut être faite quant à l'exactitude ou à l'intégralité du contenu du rapport, qui a été reproduit à partir d'une copie prête à l'impression préparée par le sous-traitant. Le résumé a été traduit par le Conseil national de recherches du Canada.

Copyright 1985 by
National Research Council of Canada

Permission is granted to quote short excerpts and to reproduce figures and tables from this report, provided that the source of such material is fully acknowledged.

Copies of this and other publications of the Division of Energy may be obtained by mailing the appropriate remittance (a Bank, Express, or Post Office Money Order, or a cheque made payable to the Receiver General for Canada, credit NRC) to

Publication Sales and Distribution Office
National Research Council of Canada
Ottawa, Ontario
K1A 0R6

Price: Free

Copyright 1985 par
Conseil national de recherches du Canada

De courtes citations et la reproduction de figures et tableaux du présent rapport sont autorisées sous réserve que la source en soit clairement mentionée.

Des exemplaires du rapport et d'autres publications de la Division de l'énergie peuvent être obtenus par courrier sur le paiement d'avance des droits requis (règlement par mandat de banque, mandat-exprès, mandat-poste ou chèque payables au Receveur général du Canada, crédit du CNRC) à l'adresse suivante:

Bureau de vente et diffusion des publications
Conseil national de recherches du Canada
Ottawa (Ontario)
K1A 0R6

Prix unitaire: Gratuit

INDUSTRIAL APPLICATION OF HEAT PUMPS

BRUNSWICK MINING AND SMELTING CORPORATION LIMITED

BELLEDUNE, N.B.

PREPARED FOR:

SUPPLY AND SERVICES CANADA

D. S. S. FILE NO. 015X.31155-D-2711B

PREPARED BY:

RAYMOND LANDRY, P. ENG.

BRUNSWICK MINING AND SMELTING CORPORATION LIMITED

BELLEDUNE, N.B.

MARCH 20, 1985

TABLE OF CONTENTS

	Page
ABSTRACT	v
RÉSUMÉ	vi
1.0 SUMMARY	1
2.0 INDUSTRIAL APPLICATION OF HEAT PUMPS	4
3.0 SYSTEM OVERVIEW	6
4.0 SYSTEM DESIGN & INSTALLATION	15
5.0 SYSTEM OPERATION	16
6.0 EQUIPMENT TROUBLES	22
7.0 ANALYSIS OF DATA	25
8.0 COST & SAVING	46
9.0 CONCLUSIONS & RECOMMENDATIONS	50
APPENDIX A - DATA COLLECTION	53
APPENDIX B - PIPING AND INSTRUMENTATION DRAWINGS	61
APPENDIX C - DESCRIPTION OF EQUIPMENT	65
APPENDIX D - MONITORING POINTS OF HEAT PUMPS SYSTEM	71
APPENDIX E - START UP PROCEDURE	75

ABSTRACT

An energy recovery system employing a plate heat exchanger in series with two templifier heat pumps was installed at Brunswick Mining & Smelting, Smelting Division in Belledune, N.B.

The energy source to the system is from the blast furnace cooling water circuit. Only 930 L/min or 15% of the total cooling water flow is directed through the system at a temperature varying between 30 and 60°C. The original design was calling for a more constant source temperature of 41°C. This variation therefore adds extra load on the heat pumps automatic control. The average total energy output is 1 706 161 BTU/h (500 kW) and the net average energy recuperation is 1 535 545 BTU/h (450 kW) with a system COP of 10 while the COP of the heat pumps alone average 5.

The total investment was $184 400 with a yearly payback of $47 264 based on 8 months operation/year.

RÉSUMÉ

Un système de récupération de l'énergie comportant un échangeur de chaleur à plaques en série avec deux thermopompes Templifier a été installé à la Division de la fonderie de la Brunswick Mining & Smelting, à Belledune (N.-B.)

Le système est alimenté en énergie par le circuit d'eau de refroidissement du haut fourneau. Seulement 930 L/min ou 15% du débit total d'eau de refroidissement est dirigé dans le système à une température variant entre 30 et 60°C. Le modèle original nécessitait une température de la source plus constante de 41°C. Cette variation a donc constitué une charge supplémentaire pour la commande automatique des thermopompes.

La production totale moyenne d'énergie est de 1 706 161 BTU/h (500 kW) et le taux moyen net de récupération d'énergie est de 1 535 545 BTU/h (450 kW) avec un CP du système de 10, tandis que le CP des thermopompes seules est de 5 en moyenne.

L'investissement total a été de 184 400 $ avec un taux annuel de recouvrement de 47 264 $ à raison de 8 mois de fonctionnement/an.

BRUNSWICK MINING AND SMELTING CORPORATION LIMITED

SMELTING DIVISION

1.0 SUMMARY

1.1 General:

Brunswick Mining and Smelting, under a contract with Supply & Services Canada, has installed an energy recovery system consisting of a heat exchanger in series with two heat pumps. The three component system is designed to recover some of the energy available from the Blast Furnace cooling water and to transfer this energy to the boiler make up water.

1.2 System:

The system was installed in 1982 at a cost of $222,746.00. From the start up date in December 1982 until now there have been many interruptions. Although some interruptions were caused by equipment failures, most of the interruptions were due to the high pressure cut out on the heat pump compressors. This problem was caused by the high variations in flow and temperature in our system. The instantaneous change in flow of make up water to the boiler had the most drastic effect on the system. The preliminary measure taken to solve this problem was the installation of a recirculation loop via a pressure relief valve at the outlet of the system. This greatly improved the situation by keeping a nearly constant flow of make up water through the system. The extra time allowed between the instantaneous drop in make up water demand and the reaction of the heat pump high pressure switch, permitted an automatic cycling operation controlled by the heat pump inner gas bulk thermostats to shut down the compressors automatically.

However the problem was not totally resolved by this change. The source water from the Blast Furnace also varies, but in temperature instead of flow. The changes in this case are more gradual. Yet the rise in temperature at times is sufficient to boost the efficiency of the heat pump to the point that the temperature in the make up water loop picks up too quickly for the thermostat, again resulting in high pressure cut out.

Different measures taken to solve this problem lead to the observations that the same heat pump with lower refrigerant content had a reduced capacity with little or no reduction in efficiency. This reduction in capacity allowed the system to run on a continuous basis. An eight months continuous operation is desired. The optimum refrigerant content for such an operation still remains to be found. To do this, a trial and error method will be used. The manufacturers were told about this and they believe it will have no effect on the integrity of the heat pump.

Data Collection

The original concept consisted of collecting data on a daily basis and to record it on a special form. To improve the quality of the recorded data, a data logger was later installed. The data logger consists of a Commodore SuperPet micro computer, an MPC-8 signal conditioning input/output system, and a long distance serial data communication link.

The data is collected during the scan period which is now set at two minute intervals. Every 30 minutes, average values for that period are stored on the Commodore 9090D solid disk.

This data logger is very versatile. Although it is not easy to program, it has the capacity to perform graphic analysis of the data, in line graph or scattered graph form. Such graphs are very useful in analysis of the data.

INDUSTRIAL APPLICATION OF HEAT PUMPS

2.0 The Use of Heat Pumps as Energy Recuperators in Industry

Until today, heat pumps had been mostly used for heating and air conditioning in the domestic environment. Industry in the past, and still today make extensive use of tube and shell and plates heat exchangers. In most applications, the grade of heat available can be applied to this type of energy transfer. Nevertheless some areas of industry require high grade heat when there is only low grade heat available. This is where the heat pump becomes a valuable tool by being able to extract energy from one source and to transfer it to another medium at a higher temperature than the source itself, with minimum energy input outside the energy source.

Brunswick Mining & Smelting Limited has been experimenting with a water heat pump system, under a contract with "Supply and Services Canada". In agreement with this contract, and also to fill a need in the industry, this report attempts to demonstrate the results of the research carried out on this project.

The response of the system under varying parameters will greatly help a future user in selecting the proper equipment for its own specific use.

Data was gathered, regarding the design, installation, maintenance and operation of the system.

The operating data was first collected by reading all meters during the daily visit to the site, and recorded on a predesigned form (see Appendix "A" Data Collection). A computerized data logger is now in operation and the collected data are stored on a hard disk. The data can later be retrieved from the disk, for study purposes. Graphic programs have been set up for visual aid in the study of data.

The following discussions highlight BMS experience with the heat pump and heat exchanger system. It includes a detailed overview of the system. The problems encountered are well defined in the 'operation' chapter. Another chapter on cost, and saving indicates the detailed cost of equipment, installation and maintenance, and a calculated saving per year based on all observed factors affecting the system. Much of the discussions focus on the efficiency of the system and the efficiency of each individual unit.

Because of the random type of failure, the heat pump operation was never continuous for long periods. Although it was not possible to compare our steam plant cost to previous yearly costs, we were able to analyse the average savings per year by considering all the factors affecting the system. This study will not only help Brunswick Mining & Smelting in their future installations, but it can also aid other firms in the cost evaluation of similar projects.

3.0 SYSTEM OVERVIEW

3.1 Furnace's Cooling Water Circuit

The Blast Furnace and the Copper Reverberatory Furnace at Brunswick Smelting are both cooled by an external jacket system. Water is the cooling medium and with reference to Figure 1, "Cooling Water Flow Diagram - Blast Furnace & Copper Reverberatory Furnace", the water flow circuit can be described as follows:

During summer operation, water is pumped from the hotwell into a head tank from which it is fed by gravity to the jackets of the two furnaces. It then returns by gravity to the hotwell and is recirculated. During the summer, softened raw water at an average temperature of 10°C is added to the head tank and the overflow is piped by gravity to the hotwell.

The cooling water is introduced to the furnaces at a nearly constant rate and the average total flow is 9,100 litres per minute. The Blast Furnace accounts for an average of 7,300 litres/minute. The outlet temp. at the Blast Furnace is usually about 40°C, but it can reach 60° before an alarm is heard. It can also go down to a much lower temperature during low blast conditions in the furnace. There are 34 (1½" diameter) outlets from the furnace jackets. Thermocouples were installed at each outlet and are now monitored on an Omega data monitor installed in the furnace control room. Automatic control valves may be coupled with these thermocouples in a future project. The outlet water temperature will then be kept constant.

3.2 Heat Pumps

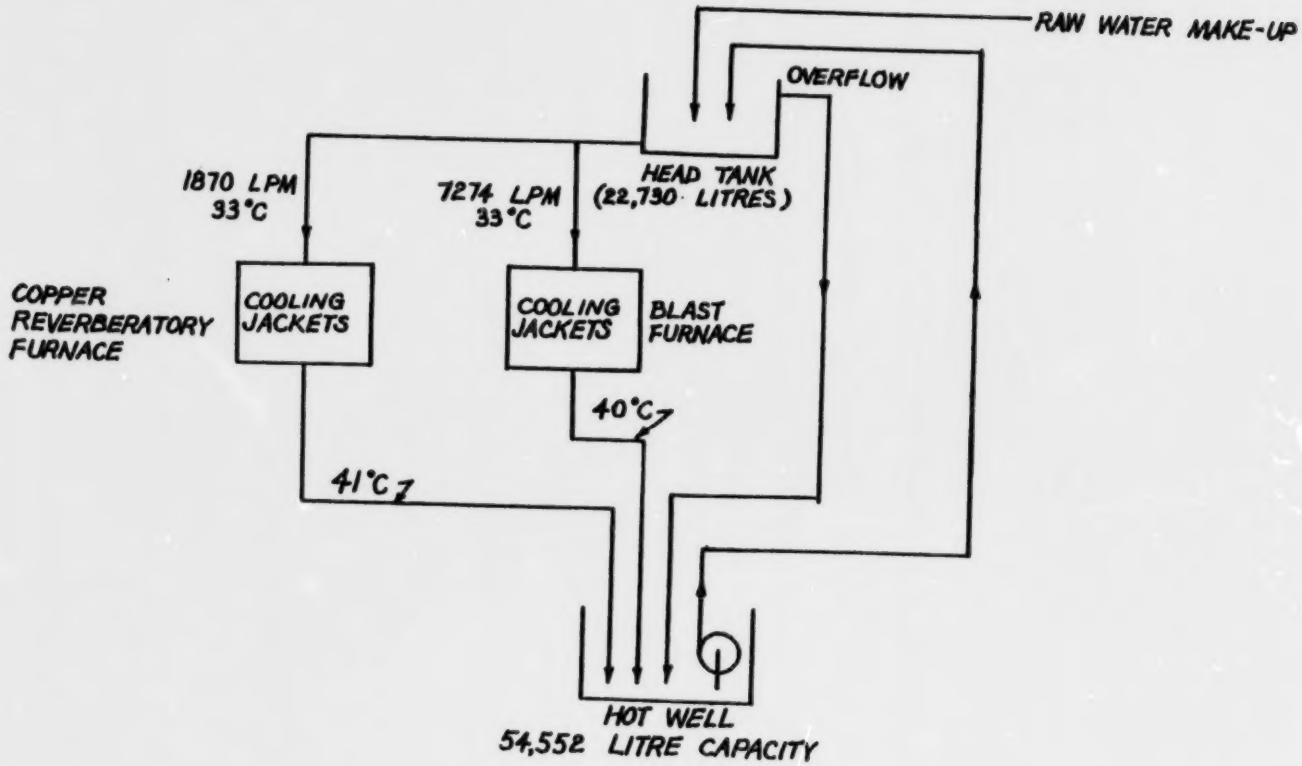
(a) General

A plate heat exchanger in series with two heat pumps extract heat from the blast furnace cooling water thereby reducing the need for additional raw water. The waste heat from this cooling water is absorbed in the heat pump evaporators by the units' working fluid (refrigerant) which is then increased in temperature and pressure by the compressors. From here it goes to the condensers where this heat is transferred to the boiler feed water for the provision of useful heat at temperatures about 71°C. The piping and instrumentation drawing in Appendix 'B' shows the detailed flow cycles that are described below. Description of Equipment is included in Appendix 'C'.

(b) Description of Flows

There are two independent water streams flowing through the system. The first is the flow of water from the Blast Furnace cooling circuit which is the source of the waste heat to be recovered by the heat pumps. Approximately 15% of all the water circulating in the furnace cooling jackets is routed through the heat pump system by three parallel routes. One route is through the heat exchanger with its own circulating pump carrying a flow of 350 L/min. The other two parallel routes go through the evaporators of heat pump #1 and heat pump #2, each route carrying a flow of 303 L/min. There is only one circulating pump responsible for the flows of these two routes. Finally, all three routes
are joined at their outlets in one drain line to the hotwell. From the hotwell, the water is pumped back to the Blast Furnace cooling water jackets.

FIGURE 1: COOLING WATER FLOW DIAGRAM
BLAST FURNACE AND COOPER
REVERBERATORY FURNACE



The second independent water stream is the flow of soft raw water from the softening plant. This flow provides the make-up water for the boilers. After being treated the water is pumped through the plate heat exchanger at a rate of 92 L/min at 1°C. The water temperature at the outlet of the heat exchanger is approximately 37°C. At that point the direction of flow will normally be toward the condensers of heat pump #1.

In the case of a failure in the two heat pumps, solenoid valves SV1 and SV2 will be energized and the flow will then be directed to the boiler. There is also a manual gate valve to bypass the heat exchanger, if it is not operating. This bypass can also provide a means of monitoring the efficiency of the heat pumps without the heat exchanger.

On normal flow operation the water flows from the heat exchanger output at a temperature of 37°C to the condensers of heat pump #1. Leaving heat pump #1 at a temperature of 57°C it enters the condensers of heat pump #2. Finally, the water temperature is raised to 71°C inside heat pump #2 and then the water is directed to the boilers. The monitoring points are shown in Appendix 'D'.

3.3 Data Logging System

The main components of the system include a microcomputer SuperPET, an MPC-8 Signal Conditioning Input/Output system, a long distance serial data communication link and compatible software.

(a) The Microcomputer

Commodore SuperPET : It is also referred to as the CPU (Central Processing Unit), acting like a brain of the monitoring system. Its main functions are to run the data logging programs which will be described in the following 'software' subsection, and to control the input/output (I/O) system. In other words, it is the medium which allows communications between the system and the users.

(b) The Input/Output System

The Dynage MPC-8 Signal Conditioning System consists of the following I/O components:

1 - 8711A I/O rack for 14 modules.

1 - 8551 12 bit, analog to digital converter (A/D)

4 - 4161 16 input analog multiplexer.

5 - 8609 4 digit, dual BCD counters.

1 - hold-down bar and cable tray.

1 - QTC-1 Power Supply with OVP (Over Voltage Protection).

1 - 8252S Serial Interface Multiplexer.

The I/O system enables the microcomputer to be applied to process monitoring. In a simple manner, the operation of this I/O system is described as follows:

The temperature data from each of the 21 thermocouples is sent in electric signals format (called analog input) to the 4161 analog multiplexer. Then the output from the multiplexer goes through the 8551 A/D converter.

Coming out of the converter in digital signals, this information then enters the 8252S serial interface multiplexer, waiting for the transmission through the data highway to the CPU (SuperPET) in monitoring room.

Similarly, the information from the flow meters and kilowatthour meters are transmitted in pulse format to the 8609 BCD (Binary Coded Digit) counters, which gives digital signals representing the meters' readings by counting the number of pulses. Then these signals are directed to the 8252S serial interface multiplexer with the thermocouples' temperatures information, waiting for the transmission to CPU.

This whole process is called 'scanning'. It starts only when the CPU (SuperPET) sends a signal/command to the I/O system, indicating the demand of readings.

This waiting period mentioned above is within milliseconds. However, it takes longer time (say 15 seconds) in order for all the data to be transmitted to the computer. Of course, there are many steps involved during the transmission period which is beyond the scope of this report.

(c) <u>The Serial Data Communication Link</u>

It is sometimes referred to as 'data highway'. This link consists of a data communication interface RS-422, a duplex telephone line and two couplers/modems. All these components work together for the transmission of data from the I/O system located in the furnace building to the computer's CPU in the office building.

(d) Software

The basic software provided by Control MicroSystems Inc. contains three computer programs namely, "2001 log #", 2001 log #1" and "2001 data". The first two programs, "2001 log #" and "2001 log #1", operate in strict relation to one another. In other words, running either one is actually running both of them. In fact, they were just two parts split from a large program. There are two reasons for this: the first is that the memory space (Random-Access Memory) of the Computer is not large enough to hold the total size of these two programs, the second is the splitting enables the program to be executed faster. These two programs are together called Data Logger.

The Data Logger programs, used in conjunction with the hardware described before in this report, allows the user to monitor, log and alarm up to 128 analog channels. The screen display shows the current time, the name of up to 128 different measurement signals, the units of each signal, the measured value in engineering units, and the alarm status. Each measured channel has two alarm levels, high and low, which are specified by the user by entering data during the set-up phase.

The existing screen display consists of three pages of information covering 75 channel readings as well as 12 calculated results. Screen displays and description of channels are appended. Only one page at a time can be displayed and it will be updated automatically after each scanning. Any of the three pages of display can be selected as the one to be viewed with the readings thereof updated.

Also the readings on any of the pages can be frozen (i.e. not updated) to allow a viewing time of a block of results. Every screen display can be dumped onto the printer if desired.

The user may vary the scan period (time interval between each scan) from a minimum of once every 15 seconds to a maximum of once every 24 hours.

Data can be stored on the Commodore 9090D solid disk drive or 8250 floppy disk drive at any interval specified by the user between 20 seconds and 24 hours. Every channel value stored is the average reading for the period since the last storage time.

The third program "2001 data" is a file-management program. Its functions are to retrieve, display and print files which contains data collected by the Data Logger. Unfortunately, there were some errors (bugs) in the Data Logger affecting the proper functions of this program.

An upgraded version of the Data Logger was written by (Jacob) "Kwok-Kuen Chik. The new Data Logger consists of two programs, "Jaclog #" and "Jaclog #1", the following features are added to the new version:

1) <u>Screen Display</u>

   - Two screens of Blast Furnace Water Jackets layouts (the top and the bottom water jackets).
   - One screen of Furnace Outlet Water Jackets layout.

- One screen of Heat Pump Data.
- Automatic mode allows the four screens mentioned above to be displayed automatically, in sequence, after each scan.

11) Data Printout

- Water jacket temperatures can be printed in graphical format. Furthermore, "2001 data" can now read the data files generated by the new Data Logger and give the desired readings. Two more programs, "Correlation" and "Plotdata", were written for the purpose of data analysis.

4.0 SYSTEM DESIGN AND INSTALLATION

A complete package of installation and piping design was issued in Summer 1982. The major concern in the design format was to make sure the units in the system could operate individually as well as in series with each other. Excessive piping and isolating valves had to be used to make such a system possible.

The heat pumps and heat exchanger were chosen in relation to the energy source and energy demand. The original design was later modified to remedy the various problems encountered.

Installation was done by Brunswick Mining & Smelting maintenance department. The installation was completed without any major problems.

5.0 SYSTEM OPERATION

5.1 Start Up

On start up in December 1982, definite procedures were followed to eliminate the leaks in the piping system, and to verify the flow in comparison to design values. These procedures were explained in the start-up chapter of the second interim report. A copy of the starting procedure is enclosed in Appendix 'E'.

The suppliers were requested to send a technician for the start up of the heat pumps. A major problem came up in the first day of operation. The problem was the sudden drop in make up water flow. This is described in more detail in Appendix 'E' start up procedure Modification paragraph.

During the design phase, it was anticipated that the flow would vary gradually relative to the float controlled valve in the deaerator tank at the boiler house. In fact what was happening was a sudden stop in make up water flow. This was attributed to the back pressure on the line when the condensate return pumps were activated. Each pump comes on line when the adjacent condensate tank is full.

5.2 Modification to System

Modification to the system was definitely required. A recirculation loop was installed. The loop operates on the principle of pressure drop through the system at design flow. A drop in make up water flow leads to an increase in pressure at the outlet of the system. A pressure relief valve was installed in that location. The water released through the valve is piped back to the make up water pump suction. The valve modulates according to the pressure buildup over the relief setting. A slight increase in pressure at the outlet of the system increases the flow through the valve.

The addition of this loop allows the make up water to recirculate through the system thereby picking up temperature gradually. The heat pumps inner gas bulb thermostat can then control the four compressors on automatic sequence.

Since the installation of the recirculation loop, many attempts were made to set the pressure relief valve for optimum operation. The aim is to obtain continuous operation with minimum water recirculation.

The task became nearly impossible with the fluctuation of the source water temperature from the blast furnace. The efficiency of the system is proportional to the source water temperature. This became an important factor when the make up water demand at the boiler dropped instantaneously. A higher efficiency caused the water in the loop to heat up faster than the reaction time of the thermostats.

This consequently caused the heat pumps to cut out on high pressure.

5.3 Operation Winter 1983-84

During winter 1983-84, the heat pump operation was not continuous. The interruptions were mostly caused by the tripping of heat pump No.1. In fact the pressure in No. 2 compressor of that heat pump was constantly higher than in No. 1 compressor, by about 20 psi. It was therefore the first compressor to cut out on high pressure. In the same period we seldom lost heat pump No. 2. Heat pump #2 is a later model. The high pressure cut out is set at 360 psi instead of 300 psi as for No. 1 heat pump.

The advantage of the newer type is that the maximum temperature output on the TPB Model is 71°C instead of 65°C. Such an advantage can be appreciated in any installation, but at Brunswick Smelting the advantages were twofold. Along with an increase in output temperature, the higher pressure cut out setting allowed more time for the heat pump thermostat to react.

McQuay engineers were asked if the high pressure cut out on No. 1 heat pump could also be set at 360 psi. This could be done, providing the pressure relief valves on the condensers were upgraded from a 350 psi to 400 psi pressure relief setting.

It was then arranged with Bathurst Refrigeration, a local Company, to order the new valves. Delivery for the valves took many weeks. Finally the valves were installed during the summer 1984.

5.4 Boiler Shutdown

During the spring of 1984 small electric boilers were installed at strategic locations on the plant, in an attempt to shut down the three master boilers during summer operation. The project was a success, and the boilers were shut down for four months of the summer. This consequently dropped the demand for make up water to zero and shut down the heat pump for the same period. It was late in the fall before they were put on line again. A leak developed on compressor #2. Refrigeration people were called in to repair the leak. Incidently both heat pump's refrigerant content was lowered in the process. They were actually refilled as if they were standard domestic heat pumps. Although it wasn't intentional it lead us to some interesting observations. First the four compressors ran for 2 months without any interruptions. We also realized that the total capacity of the heat pumps was down by approximately 40%. The interesting part is that the power demand of the units was also down by about 40% thus keeping the coefficient of performance constant. This was a quick indication that the system could be modified for lower demand and still maintain the same efficiency, it is more an observation than a scientific discovery. Our assumptions were therefore verified with the manufacturer. Although they had never heard of such application, they could not foresee any further complication. In fact the heat pumps were operated for two months without any visible damage to the machine.

5.5 Latest Operation

For the purpose of this study, all compressors were refilled with refrigerant to a content slightly above recommendation. Once on line the heat pumps operated only for one day before a leak developed on heat pump No. 2. It was traced to a high pressure cut out switch. Since the break seemed to be caused by vibration, the faulty instrument was changed and the compressor refilled to the same running pressure.

Very valuable data was obtained during the first days of operation. Make up water temperatures of up to 75°C were attained. This data is analysed in the 'Data Analysis' chapter of this report. Demand for steam has now dropped slightly and the compressor runs for variable periods depending on the source water temperature.

5.6 Future Operation

In the 'Third Interim Report' future improvements were discussed. Three areas of interest were found, namely the propane vaporization, the change house shower area, and furnace building heating. The first two areas of interest demanded such high initial cost, that the ideas were dropped. The project for furnace heating may still go ahead, it would only be to improve the operation of the heat pump if no better solution is found. In fact, the furnace building is highly ventilated and the energy distributed would mostly be lost to the atmosphere.

From now on the boilers will be shut down during summer months. Only eight months of heat pump operations will be required, from October until May. Steam demand varies during those months and it will be necessary to adjust the capacity of the heat pumps accordingly. A compromise will be necessary. During the cold winter months the system will not deliver the make up water at maximum temperatures, but on the other hand it will be able to operate at the lower demand of fall and spring months. The proposed way to approach this optimization is to release some refrigerants from one heat pump at a time and then observe its operation. This will be a trial and error method which will be accomplished during the spring months. The data logger will be of great help in this optimization.

6.0 EQUIPMENT TROUBLE

During the study period we experienced some trouble with the following equipment: 1) Heat pump compressor, 2) the circulation pumps, 3) strainers and flow meters, 4) solenoid valve, 5) automatic air release.

The following discussions explain each in detail:

1) Heat Pump Compressor

Compressor #1 on heat pump #1 failed after only two weeks of operation. This was immediately reported to the Manufacturer (McQuay). We were then asked to perform several tests which only showed that the compressor had to be replaced. McQuay provided a new compressor free of charge but it took four months for delivery. Non standard voltage and out of stock were the reasons for such a delay.

The new compressor was installed by a local company. There has been no other failures.

2) Circulation pumps

Two pumps were included in the system design. As described in 'System Overview' of this report, one pump provides source water to the heat exchanger and the other pump provides source water for the two heat pumps. This last pump started to give trouble after a few weeks of operation only. The first failure was the factory installed, pump to motor coupling. The coupling was replaced and the alignment rechecked. A second failure occured again after a few weeks of operation.

This last coupling was replaced with a more flexible type which lasted much longer. Finally the pump bearings failed. No defect was found on the pump once dismantled in the shop. A new set of bearings were installed and the pump was put back on line. This was the last problem with these pumps.

3) Strainers and Flow Meters

On the source water side in order to protect the flow meters, it was necessary to install a screen with fine mesh (3/64"). The neptune flowmeter consists of a rotating sphere which gets damaged by fine particles. The fine mesh screen started to plug very fast. They actually had to be cleaned every week. This maintenance was carried on all through the heat pump operation. During summer 1984 when the heat pumps were down, sandblasting operation took place in the area. Even with protection a small layer of sand was deposited in the blast furnace cooling water launder.

On start up during the fall of same year, the strainers were plugged solid from the sand carried by the source water. They were impossible to clean. Because of the amount of sand left in the furnace cooling water circuit, the new screens were also plugged in matters of days, a decision was then taken to change the screen to bigger mesh (1/16") to the detriment of the flow meters.

The possibility of losing the flow meters on the source water side is not all that terrible. Previous observations have shown that the flows through these meters are rather constant. Any variations in the flows meant that the screens

were plugging up. This should not happen again with larger mesh screens, if it does, the temperature drop through the heat pump will be a good indication.

A constant value for each flow was then entered in the Data Logger program. A lack of precision in that flow will only have effect on the "Total BTU Loss of source water through the System". It has no effect on any other calculation in the program.

There was no need for any change on the make up water circuit since it is very clean. The screens are fine mesh and therefore can protect the flow meter on that circuit.

4) Solenoid Valve

The solenoid valves were installed to ensure a continuous optimum operation in case of failure of one unit while the system was unattended. It was a luxury which proved to be a burden. The pressure drop across the valves is excessive and the valves also tend to freeze in their normal position if not energized for a long period.

5) Automatic Air Release

The automatic air release was installed at high points in the piping, to remove any air that would accumulate in the system. They did not always function and had to be dismantled a few times.

7.0 DATA ANALYSIS

For the purpose of comparing the original recording form to what is available now, both original form and data logger display are shown in Appendix 'A'.

This chapter will analyse the information stored on the solid disk during the 1984-85 winter period. Some modifications to the existing programs is necessary for such a task. It is our intention to include as much information as possible in readable form, such as line graphs and scatter graphs.

GENERAL:

As written earlier in this report, the heat pumps operation was never continuous for long periods. The data stored on the hard disk were searched for usable information. The data are stored in relative files on the hard disk and a new file name is entered from the keyboard every time the data logger program is run. Also a new number is entered automatically for every new day of data recording. Only the first two days of recording, after the program is run, can be found in the same file. For example if the program is run at 16:00 hours then the first file will contain 8+24 hours of recording. The longest period of recording without break was found on the files dated Feb. 13 to Feb. 17, 1985. The first file contained thirty three hours of recording. Since all components of the system were on line during that period, it was chosen for analysis.

It is important here to reassure the reader that the heat pumps were running at times for much longer periods without break, but at those times the data logger was either not installed or not running well.

The author also has a special interest in that data file since heat pump #1 and heat pump #2 were running under different refrigerant content, during that period. On Feb. 12, one day before the file was set up, 'Bathurst Refrigiration' was called in to increase the refrigerant content in all heat pump compressor circuits. Only a small quantity of refrigerant 500 used in heat pump #1, was available at the time. Therefore heat pump #1 was left with a low refrigerant content for the time being. On the other hand, heat pump #2 refrigerant content was raised to its design value. This kind of refrigerant (R-12) is widely used in air conditioning application and there is no availability problem.

The condition in heat pump #1 applies well to this study. The two heat pumps can now be studied under two different sets of conditions.

Graphical analysis was prepared using the data available from the two files mentioned above. Two programs were available. The first program 'Line Graph-3' was written by the author, and the second program, 'TacPlot-#2' was written by Jacob Chick. Both programs run on the data logger SuperSet.

The programs retrieve the data information from the hard disk and then build a chart on the Hewlett-Packard747SA-Plotter. Brunswick Smelting bought this plotter in 1984, along with an Hewlett-Packard 150 as part of a plant wide computer system. Software is available with the HP150 to build those charts, but we have not been able yet to set up communication between the two computers.

7.1 Line Graph

The line graph needed two sets of vertical axis units to show a relation between two or three parameters with different units. The time frame is identical for all. This way any influence that one parameter has on the others on the chart is quite visible.

All the values that are plotted on the graphs represent the average of fifteen readings taken every two minutes over a thirty minutes period. Instantaneous variation in values (eg, make-up water flow) are therefore not shown.

Drastic drops on some of the graphs indicate the time that one compressor was cycling off on thermostat. Graph #3 indicates that compressor No.2 was down twice.

The label, title, and legend on the graphs are sometimes composed of abbreviations. These are listed in Table 1. Abbreviation for condenser (Cond) and compressor (Comp) may be confusing. In fact the "Refrigerant temperature comp" is also the temperature of the refrigerant at the inlet of the condenser while the "Refrigerant temperature Cond" represent the temperature at the outlet of the condenser. Similarly "Refrigerant temp evap" represents the temperature at the evaporator outlet.

Graphs "1" to "10" are constructed with data from the file dated Feb. 13/85.

From Graph #1 it can be seen that the final make up water temperature is influenced by both the flow of make up water and the source water temperature. On Graph #2 the COP of heat pump No 1 and heat pump No 2 are compare in relation with the source water temperature. COP of heat pump #1 is slightly lower than that of heat pump No. 2.

The drastic drop in the efficiency of that pump #1 toward the end of the recording period is caused by the cycling of one compressor in the heat pump.

A slight difference is noticed between the "COP" of the two heat pumps. This is attributed to the low refrigerant content of heat pump no. 1. Although the "COP", the heat pump alone is not largely affected by a low refrigerant content, the average COP of the heat pump with the circulating pump is affected. This is caused by the lower capacity of the heat pump on low refrigerant content. While the power demand of the heat pump decrease with a decrease in capacity, the power demand of the circulating pump remain constant thus affecting the efficiency of the two machines combined.

The reader will notice that the flow of source water is never referred to in the graphs. This is because this flow is always constant and can be referred to as follows:

Flow of source water through heat exchanger	95 GPM
Flow of source water through heat pump No. 1	55 GPM
Flow of source water through heat pump No. 2	55 GPM

7.2 Scattered Graph

The scattered graph program was set up to show the correlation between any two parameters affecting the heat pump system. The points sometimes spread all over the graph. A widely scattered graph indicate that the parameters have very little influence on one another. On the other hand a trend is established when most of the points gathers along a straight line or a curve.

Graph "11" to "16" illustrate the correlation between data from file dated Feb. 13/85.

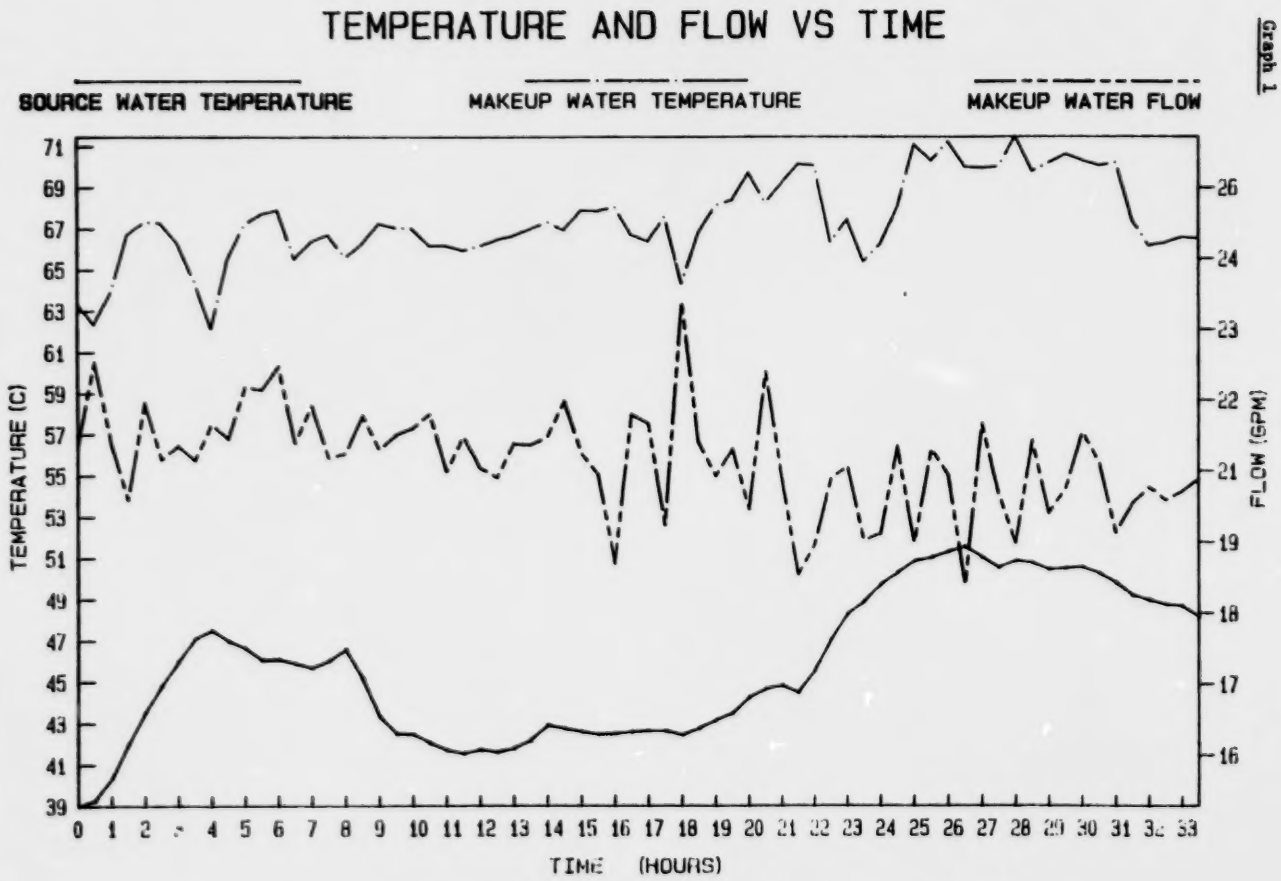
In these graphs only graph No. 11 illustrates a trend. This graph establishes a relationship between the source water temperature and the refrigerant temperature at the outlet of compressor No. 1 in heat pump No. 2. The trend clearly shows that an increase in source water temperature brings an increase in compressor temperature. It is interesting to note that the increasing trend flattens out when the compressor temperature reaches 109°C, at that point the source water temperature is approx. 50°C. A further increase in this last temperature has no effect on the maximum temperature of the compressor. This observation leads to the conclusion that heat pump No. 2 operates at its maximum capacity when the source water is at 50°C, similarly graph No. 12 illustrates a trend between source water temperature and power demand from heat pump #2. The drastic drop again shows the temperature at which one compressor was down. Graphs no. 13 to 16 demonstrate that the COP of the component or the total system are affected by more than one factor. The make up water flow, and the source water temp. are the two important factors affecting the COP of each component of the system, from these graphs, that one has as much influence as the other.

Table 1

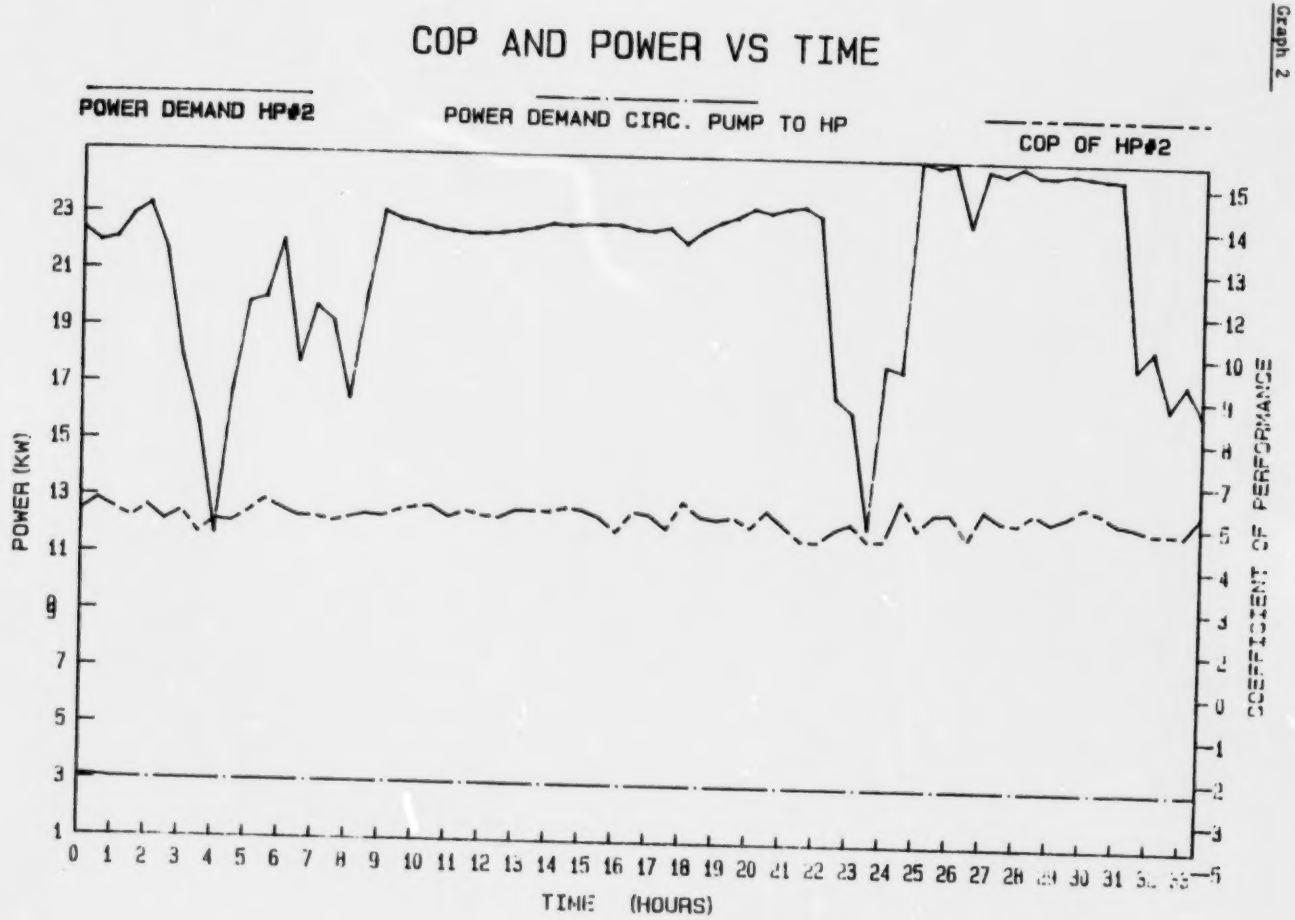
ABBREVIATIONS

"COP"	:	Coefficient of Performance (Efficiency)
HP	:	Heat Pump
Temp	:	Temperature
Comp	:	Compressor
Cond	:	Condenser
Evap	:	Evaporator
Circ. Pump	:	Circulating Pump
SCWater Temp	:	Source water temperature at the inlet of the system.
Flow (GPH)	:	Flow in Imperial Gallons per minute.
Heat Exch	:	Heat Exchanger
Make Up Water Temp	:	Make up water temperature at the outlet of the system.
Power(kw)	:	Power demand in kilowatts.
Temperature(c)	:	Temperature in degrees Celcius.

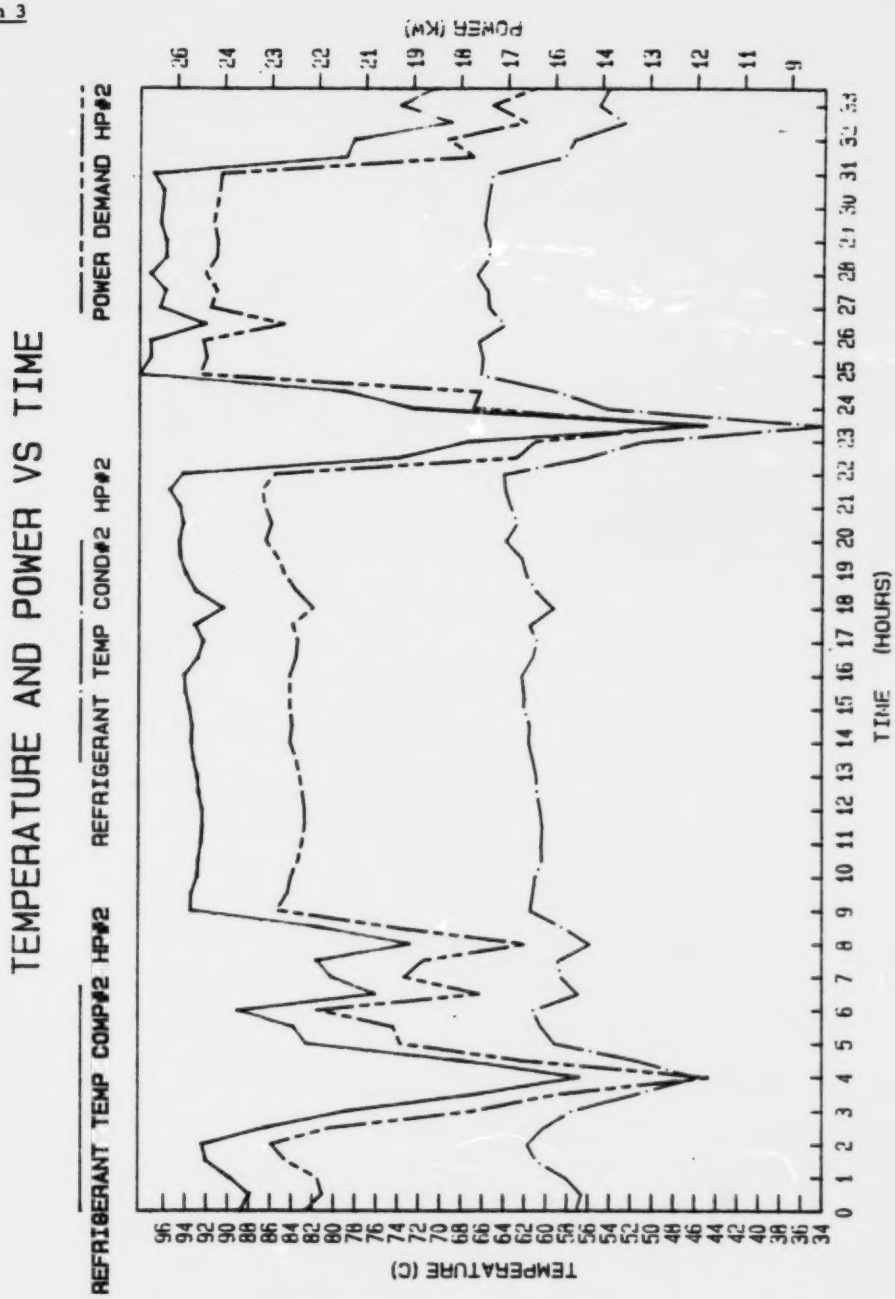
Graph 1


TEMPERATURE AND FLOW VS TIME
SOURCE WATER TEMPERATURE
MAKEUP WATER TEMPERATURE
MAKEUP WATER FLOW
TEMPERATURE (C)
FLOW (GPM)
TIME (HOURS)

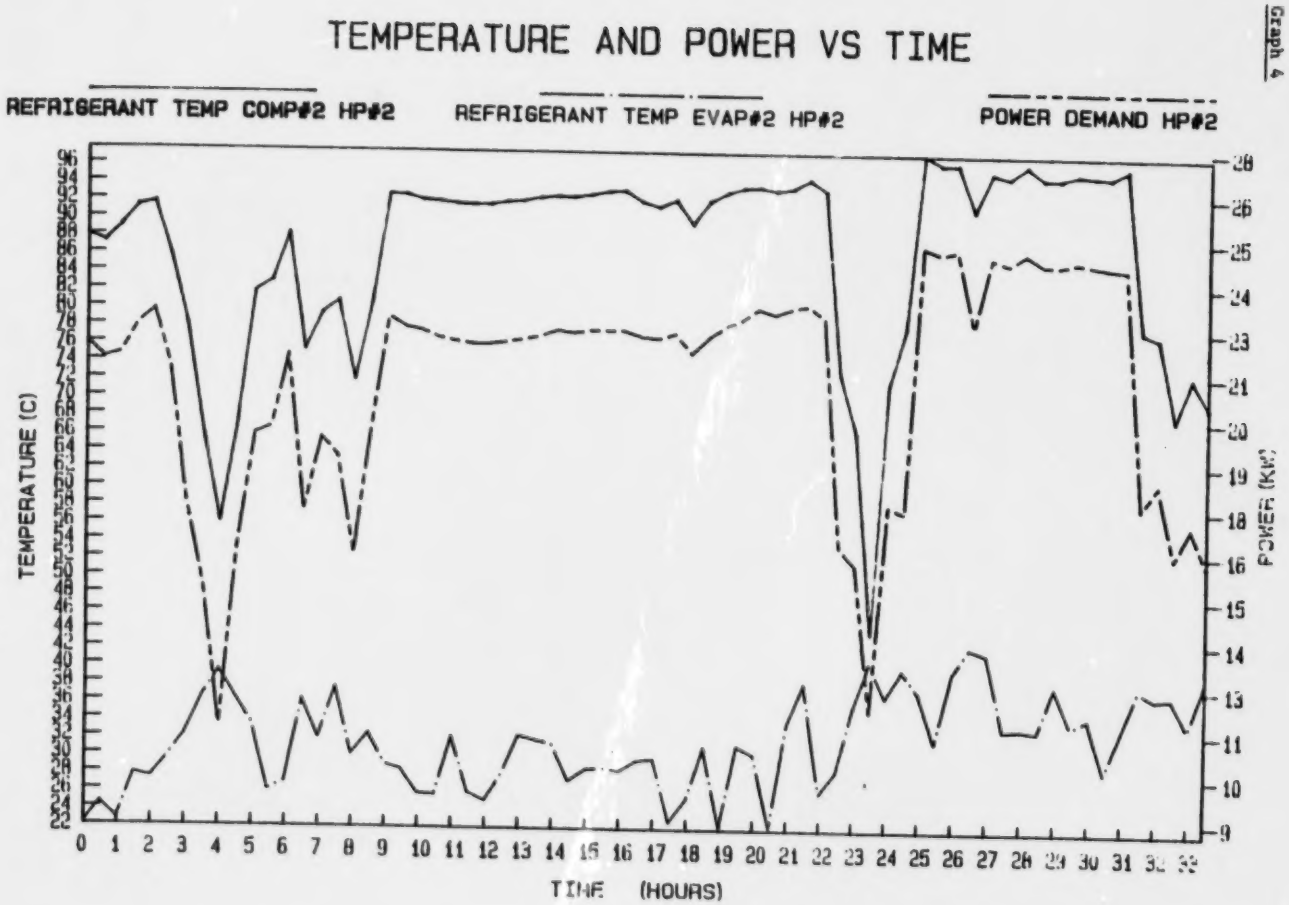
Graph 2


COP AND POWER VS TIME
POWER DEMAND HP#2
POWER DEMAND CIRC. PUMP TO HP
COP OF HP#2
POWER (KW)
COEFFICIENT OF PERFORMANCE
TIME (HOURS)

Graph 3

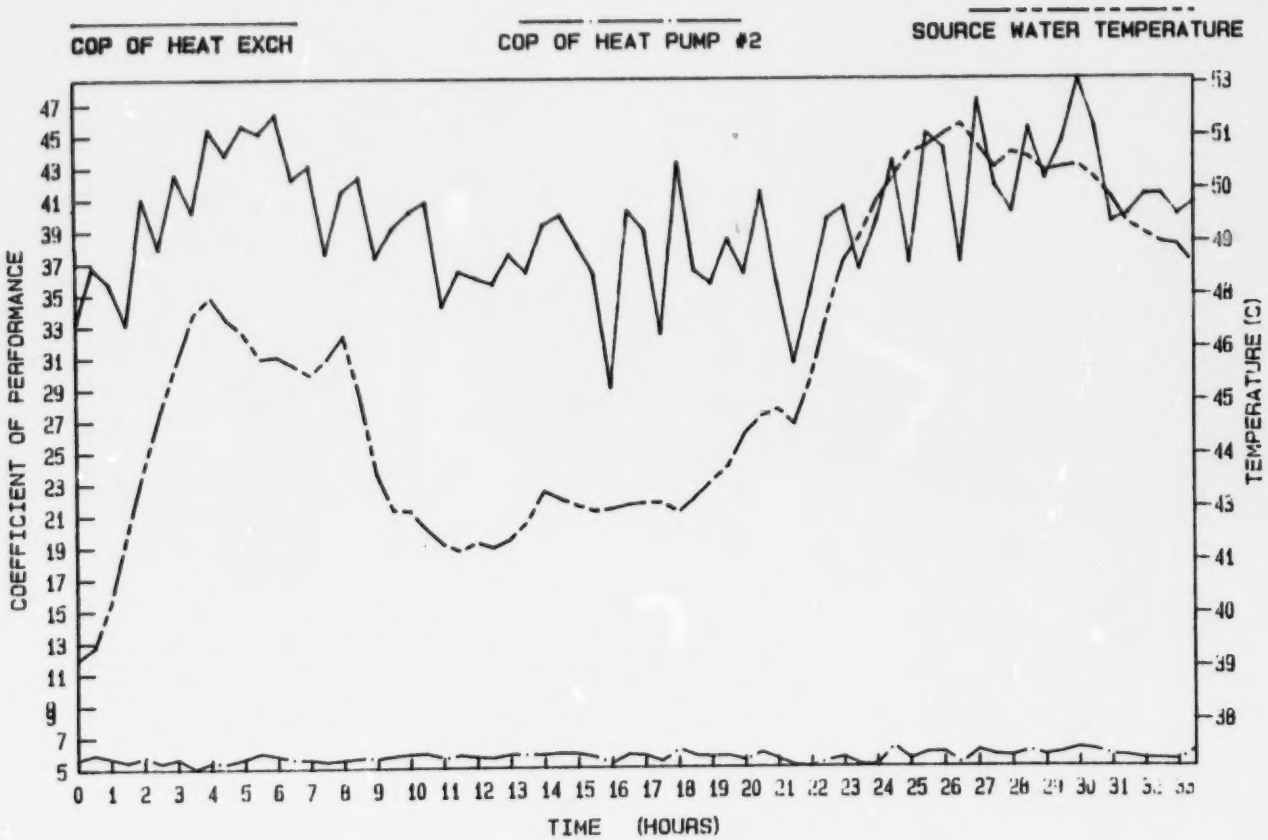

TEMPERATURE AND POWER VS TIME
REFRIGERANT TEMP COMP#2 HP#2
REFRIGERANT TEMP COND#2 HP#2
POWER DEMAND HP#2
TEMPERATURE (C)
POWER (KW)
TIME (HOURS)

Graph 4

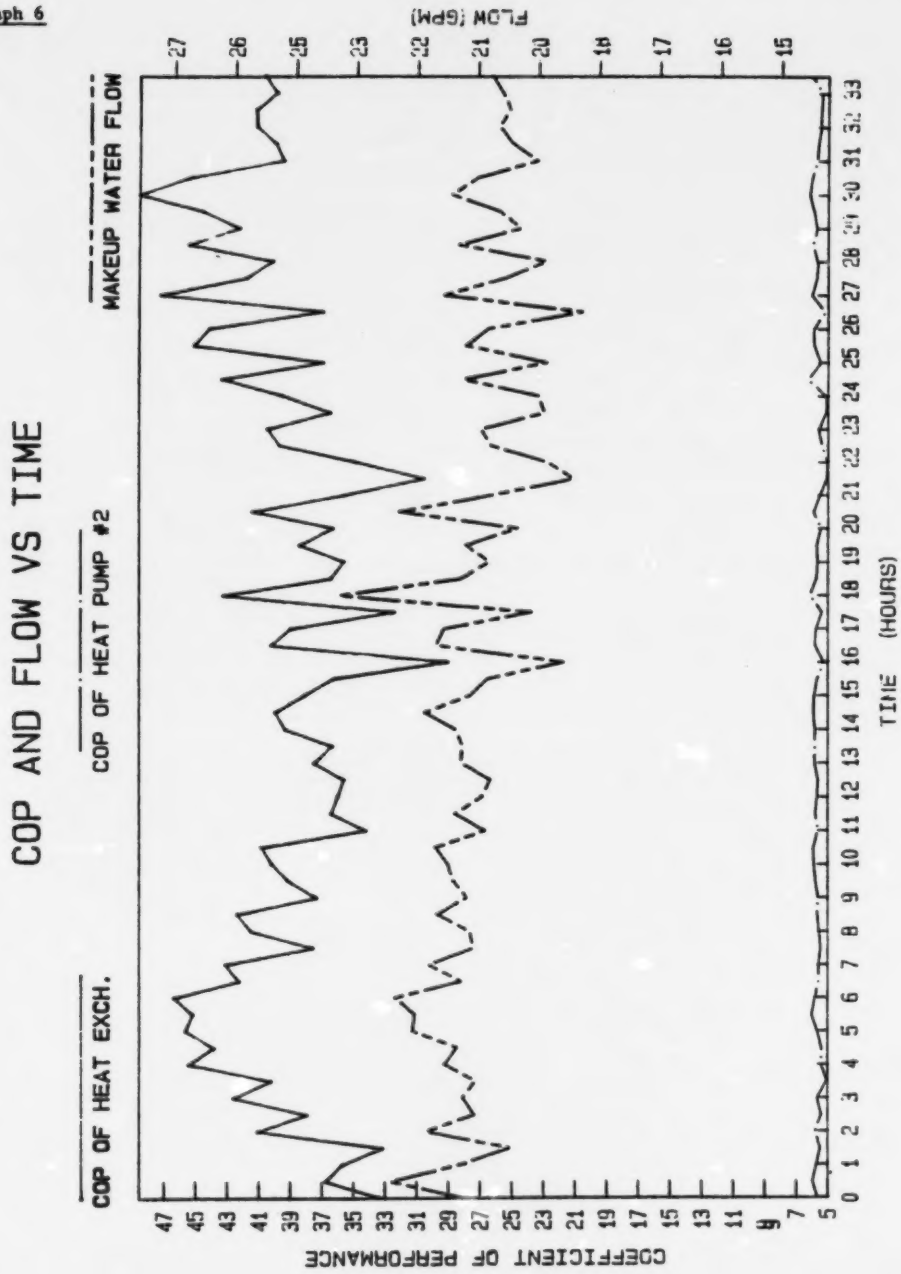

TEMPERATURE AND POWER VS TIME
REFRIGERANT TEMP COMP#2 HP#2
REFRIGERANT TEMP EVAP#2 HP#2
POWER DEMAND HP#2
TEMPERATURE (C)
POWER (KW)
TIME (HOURS)

Graph 5

COP AND TEMPERATURE VS TIME

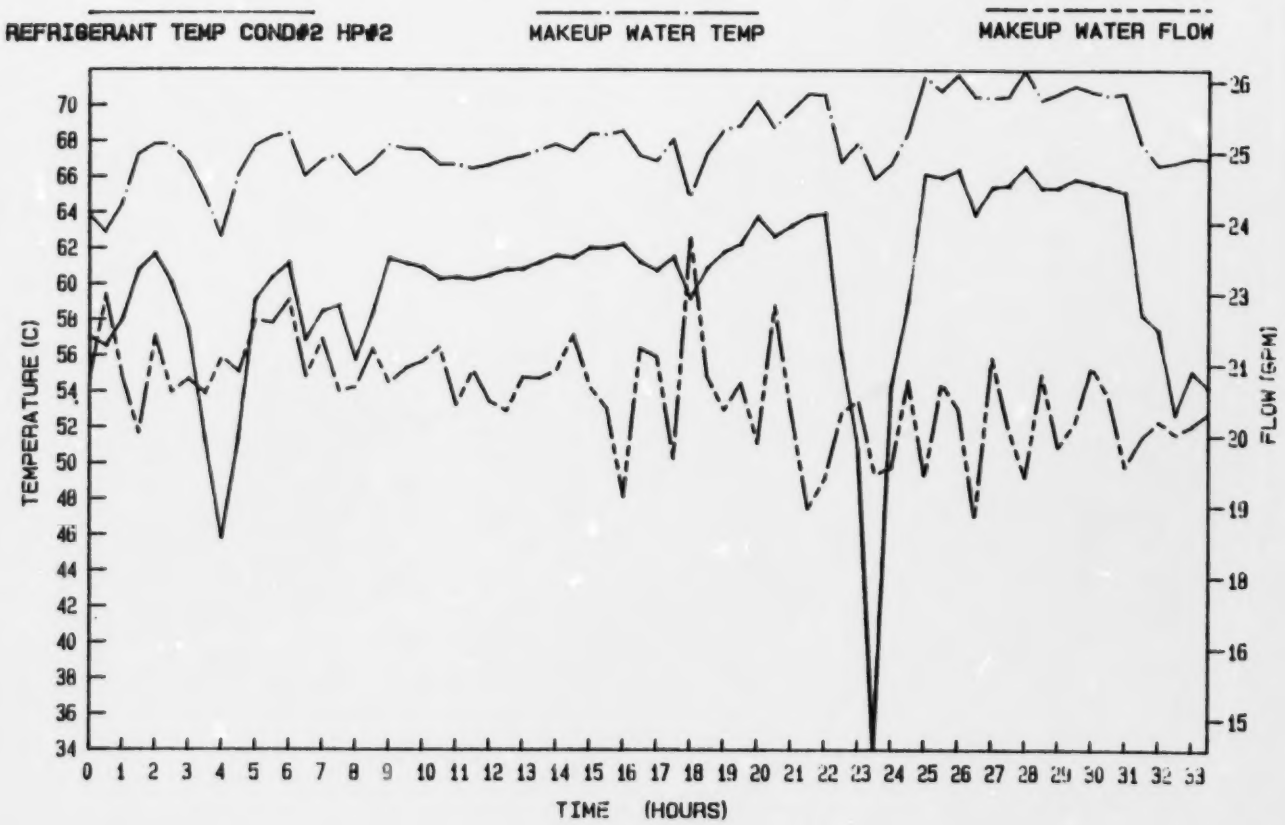


Graph 6


COP AND FLOW VS TIME
COP OF HEAT EXCH.
COP OF HEAT PUMP #2
MAKEUP WATER FLOW
COEFFICIENT OF PERFORMANCE
FLOW (GPM)
TIME (HOURS)

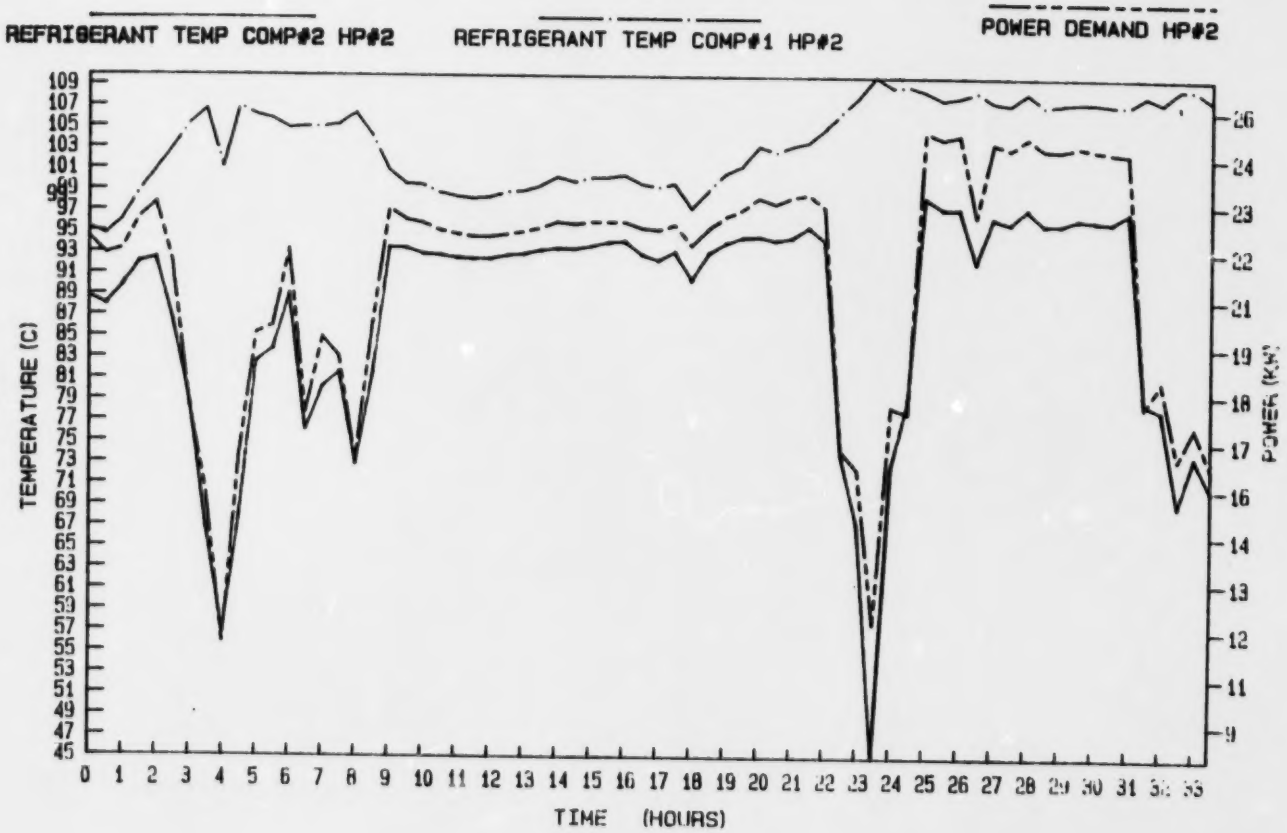
Graph 7

FLOW AND TEMPERATURE VS TIME



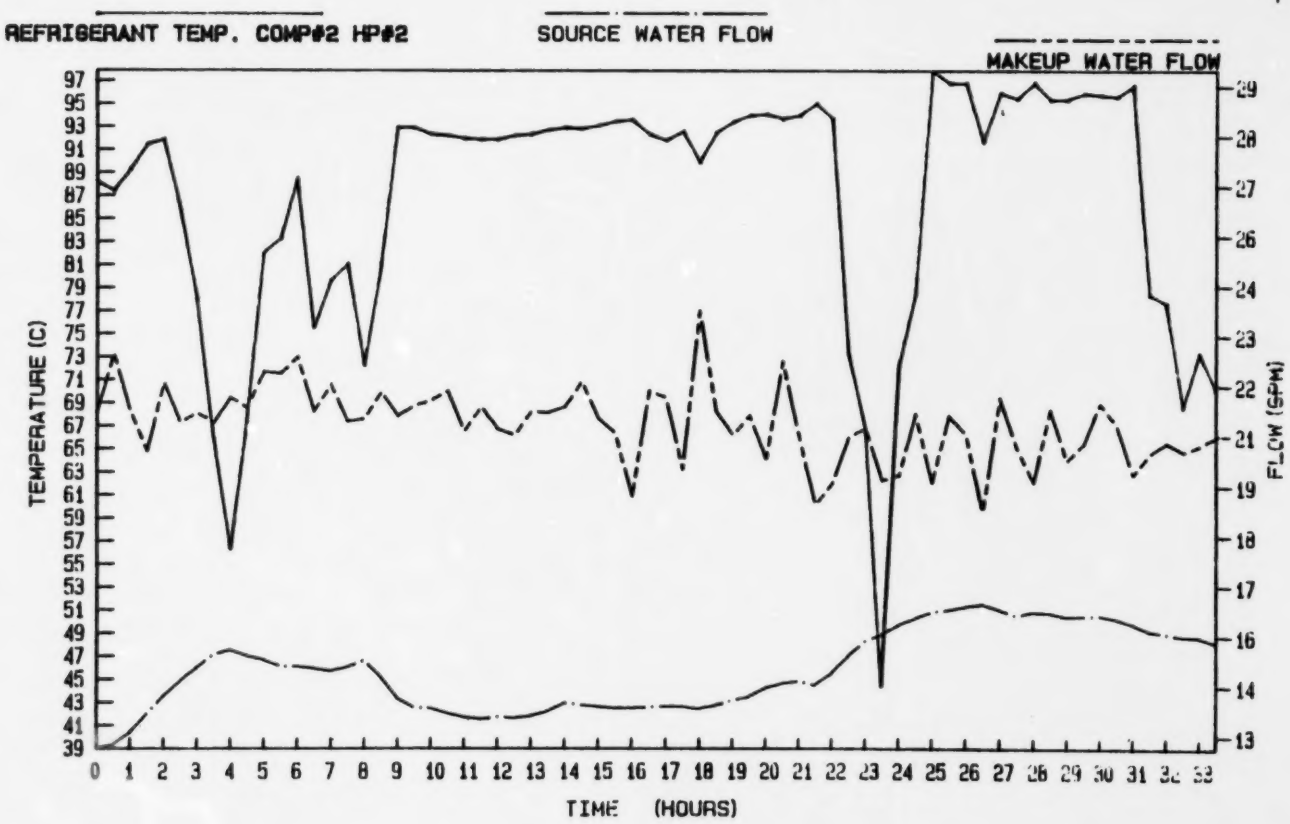
Graph 8

TEMPERATURE AND POWER VS TIME

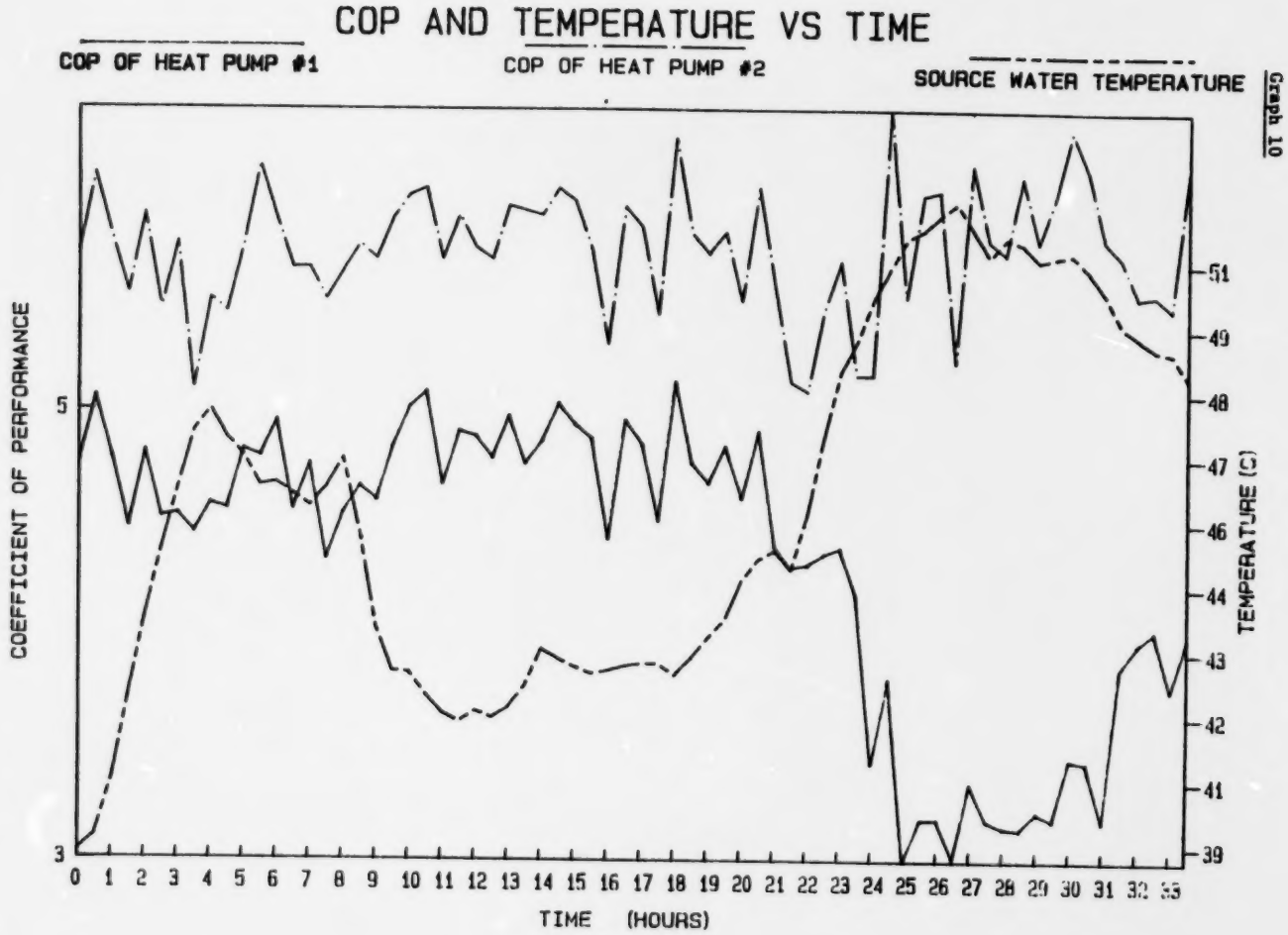


Graph 9

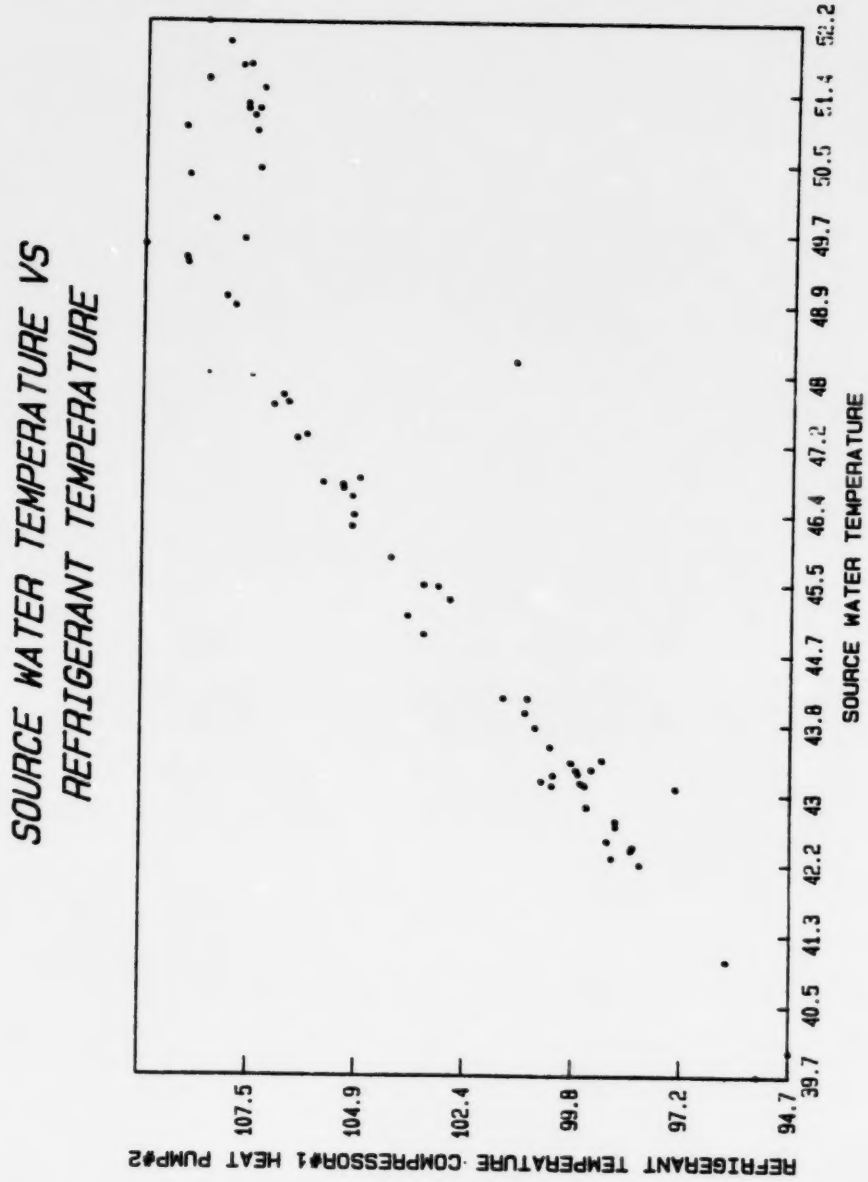
FLOW AND TEMPERATURE VS TIME



Graph 10

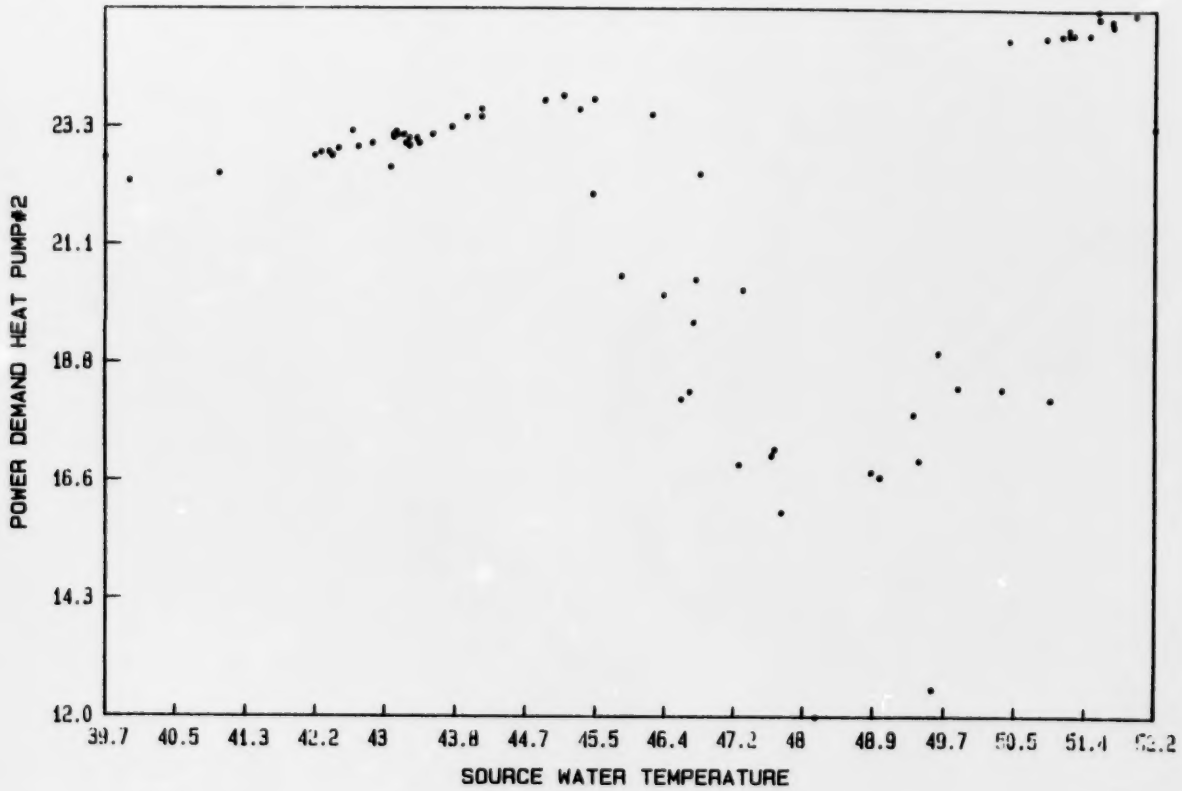

COP AND TEMPERATURE VS TIME
COP OF HEAT PUMP #1
COP OF HEAT PUMP #2
SOURCE WATER TEMPERATURE
COEFFICIENT OF PERFORMANCE
5
3
TEMPERATURE (C)
51
49
48
47
46
44
43
42
41
39
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
TIME (HOURS)

Graph 11


SOURCE WATER TEMPERATURE VS
REFRIGERANT TEMPERATURE
REFRIGERANT TEMPERATURE COMPRESSOR#1 HEAT PUMP#2
107.5
104.9
102.4
99.8
97.2
94.7
39.7
40.5
41.3
42.2
43
43.8
44.7
45.5
46.4
47.2
48
48.9
49.7
50.5
51.4
52.2
SOURCE WATER TEMPERATURE

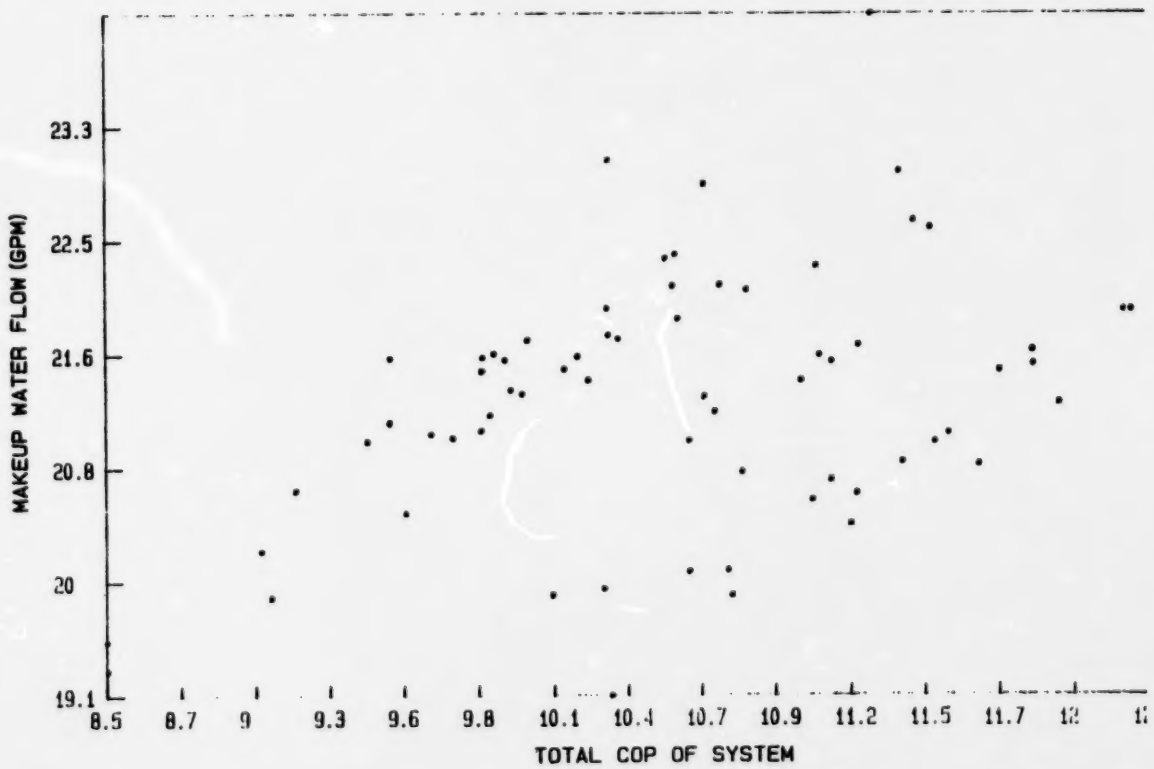
Graph 12

SC WATER TEMP VS POWER DEMAND HEAT PUMP#2

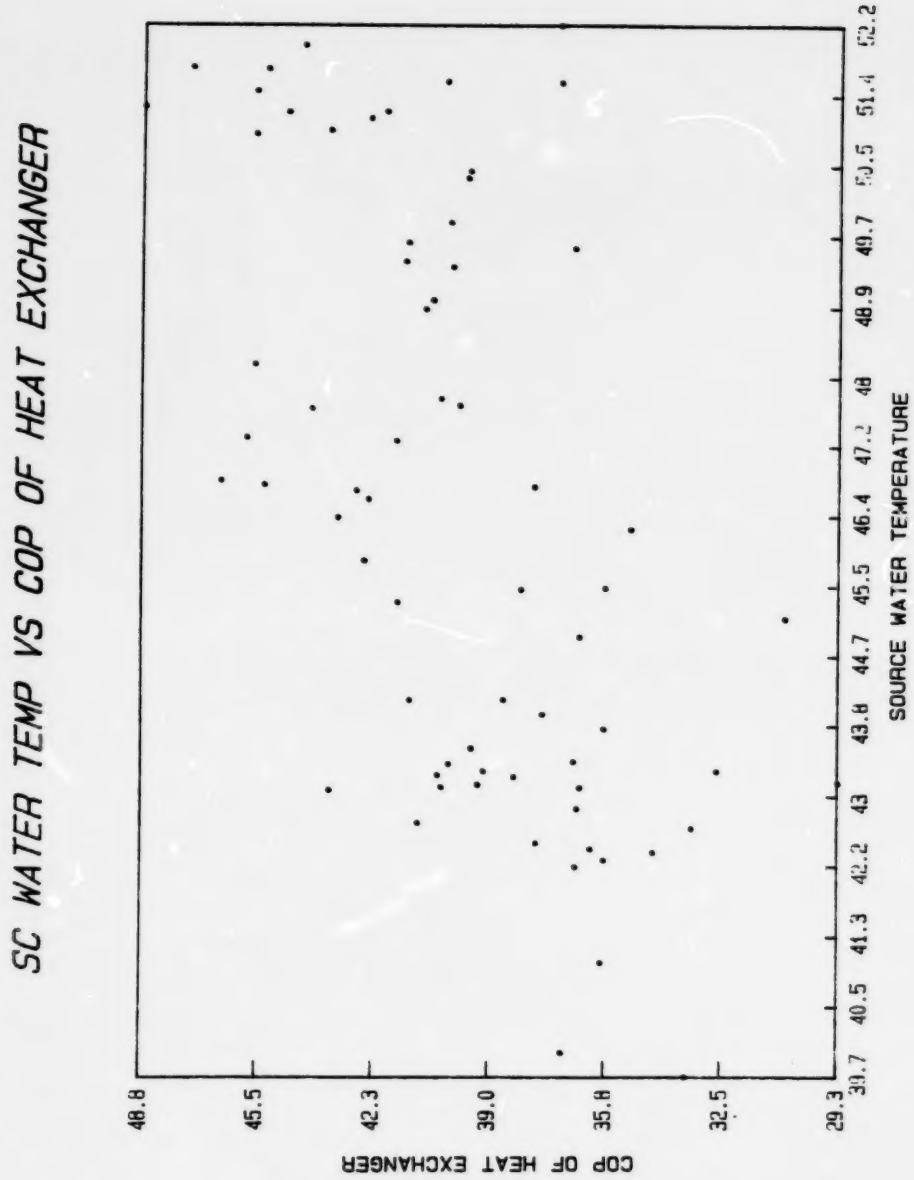


Graph 13

TOTAL COP OF SYSTEM VS MAKEUP WATER FLOW

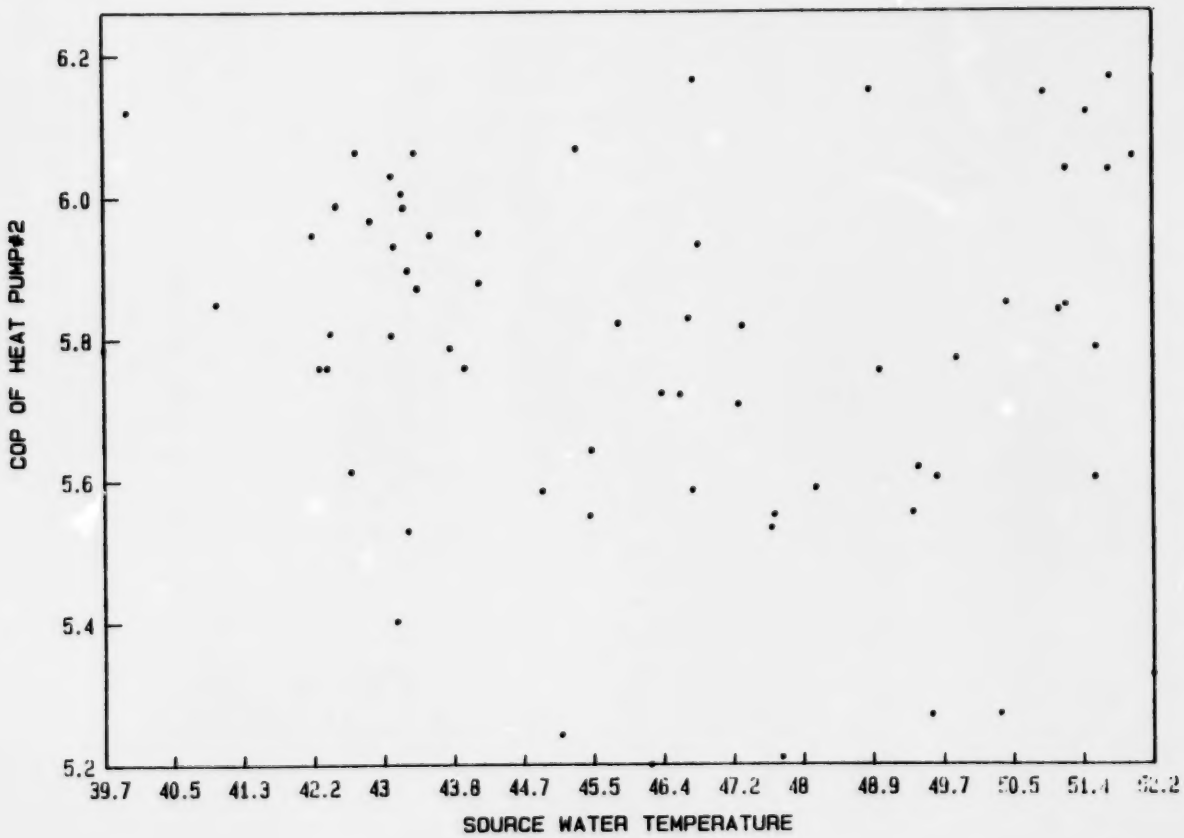


Graph 14


SC WATER TEMP VS COP OF HEAT EXCHANGER
COP OF HEAT EXCHANGER
48.8
45.5
42.3
39.0
35.8
32.5
29.3
39.7
40.5
41.3
42.2
43
43.8
44.7
45.5
46.4
47.2
48
48.9
49.7
50.5
51.4
52.2
SOURCE WATER TEMPERATURE

Graph 13

SC WATER TEMP. VS COP OF HEAT PUMP NO. 2



8.0 COST AND SAVING

.1 Cost

The overall cost of the heat pump project is broken down into sections which are detailed in table 2.

The cost of design and installation could have been much higher if not done in house. The installation was done by our best people and their efficiency compares to a specialized contractor. Their salary including overhead usually does not add up to contractor fees on any project. Brunswick Mining & Smelting "Project & Design" department provided the professional skill needed in the design of this project. The designer involved in this project has over twenty years of experience with "Simon Carves" a consultant internationally known in the industry. The cost of design was kept to a minimun if it is considered that out of the $24,700 design cost, the amount of $12,400 was allocated to a consultant for the proposal report.

The monitoring and reporting task could have hardly been contracted to outside expertise without skyrocketing in the total cost of this task. The system in its early stage needed attention continously.

.2 Saving

Many factors have to be considered in calculating a saving. The end product is actually the make-up water when it reaches the boiler house. A 5°C loss was measured from the outlet of the system to inlet of the deaerator tank in the boiler house. This loss of temperature definitely has to be accounted for.

The recirculation loop also affects the system. The real temp of the make-up water when it enters the system is mostly constant all through the 8 months usable season. This temperature is about 0°C. The recirculation loop that was added to the system affected the water temperature at the inlet of the system. Therefore the total COP of the system is actually slightly higher than what is calculated by the data logger.

Therefore the method used to calculate a real saving is described as follows:

1) Average flow of make up water over the 8 month operation = 20 GPM.
2) Average temperature of make up water inlet to the system = 0°C.
3) a) Average temperature of make up water outlet = 67°C.
   b) Average temperature of make up water at the boiler = 67°C - 5°C (lost) = 62°C.
4) Cost of energy produced by the boiler = $5.67/million BTU, based on the actual efficiency of the boiler.
5) Average total COP of system = 10.5.
6) Energy output/min (EO) = Flow x T x 18 BTU/°C/GPM/Min.
7) Total energy output (TEO) = EO x 43200 min/month x 8 months.
8) Total work input (TWI) = TEO/COP
9) Net energy saving (NES) = TEO-TWI
10) Net savings in dollars (NSD) = NES/($1x10^6$)x5.67/10^6 BTU

Therefore the energy output as per equation (6):

Energy output/MIN (EO) = 20 GPM x 62°C x 18 BTU/°C/GPH/Min.

= 22320 BTU/Min.

Total Energy Output (TEO) = 22,320 BTU/Min x 43200 Min/months x 8 months

$$= 7.7137 \times 10^9 \text{ BTU}$$

Total Energy input (EI) = $\frac{\text{TEO}}{\text{COP}} = \frac{7.7137 \times 10^9 \text{ BTU}}{10.5}$

$$= 7.3464 \times 10^8$$

Net Energy saving (NES) : TEO-EI = 6.979×10^9

Net Saving in dollars (NSD) = $6.979 \times 10^9 / (1 \times 10^6) \times 5.67/10^6$ BTU

= $39,571.23

It is evident that the values listed in line one (1) to (5) were measured from the graphics included in this report. Although they are not included in the report other statistic shows that these values are realistic.

Table 2

B.M.& S. FURNACE HEAT PUMP COST DISTRUBUTION

Section	Items	Cost
Engineering:		
Design		24,700
Monitoring and Reporting		14,750
Commissioning and testing (including data logger)		8,400
Installation:		
Direct charges	- Heat Pumps	29,200.00
	- Heat Exchanger	2,600.00
	- Circulator Pump & Motor	3,104.70
	- Pulse Initiating Meters & various transformers to accompany new data logger	7,300.00
	- Data Logger	27,747.00
	- Miscellaneous	28,672.00
(copies of purchase orders are included for reference)		
B. M. S. Store		6,624.00
Labour		29,942.00
Future Work:		
Data Logger Installation		10,600.00
Winter Enclosure and Heating		18,500.00
Overhead (5%)		10,607.00
	Overall Costs:	**222,746.00**

9.0 CONCLUSIONS AND RECOMMENDATIONS

It is visible from this report that the applications of heat pumps in industry are more restricted than can be expected from the simplicity of some commercial applications. Many factors are involved which influence the cost of design, installation, operation, and maintenance of the system.

It will seldom be possible to have all the ideal conditions. Industrial complexes similar to Brunswick Smelting will likely have massive energy sources but limited applications for medium grade heat in the range that heat pumps can supply. Some applications that were found in this study, for exemple hot water for showering, were not cost effective because of the massive piping modification that was needed. An important part of that cost is attributed to insulating and heat tracing. This type of construction is needed with any outside piping for industrial plants in Canada. Keeping this in mind it is logical to say that new industrial installations could plan ahead to cut piping to a minimum therefore giving a better chance for a cost effective heat pump application.

Any interested party in heat pump application should first look for a stable energy demand, whether it be either in heated liquid or heated gas. The varying demand in make up water flow definitely gave us the most trouble. The second important thing to look at is the source of heat available. Although a variation in the source water temperature or flow alone would not affect our system drastically, a constant source of heat is preferable.

A very important aspect of industrial application of any equipment, is the personnel available for controlling this equipment. Brunswick Mining and Smelting employs 625 people, and although the management is very proud of the work force it remains that the operator out in the field will take better care of equipment if it makes his job easier. Energy related projects seldom do that except maybe in room heating applications. Therefore heat pumps need to be almost maintenance free. It was obviously not the case in this application. Nevertheless, by choosing the right location with stable parameters as explained above, it is possible to attain such applications where maintenance can be kept to the minimum.

The most suitable heat pump for Brunswick Mining and Smelting in any future project would be a water to air heat pump. There is a massive energy source from the acid plant salt water cooling circuit. This source of energy is at the moment lost to the "Baie des Chaleurs" by the return flow to the Bay. This available energy could be used to supply heat to the acid plant during the winter. Steam is the actual heating medium for that plant. The reason for choosing a water to air heat pump instead of the water to water is its efficiency. For a plant heating application, a high volume of air at 40°C is very suitable. The condenser transferring the heat to the air will need to be about 10°C above the air temperature. In water to water heat pump the condenser temperature will have to be higher in order to transfer the heat to the heating water which will in turn transfer its heat to the air. This second type of system would also be more expensive.

The knowledge acquired during this project has lead to greater consciousness on energy related problems. While this project was going on, a new department was formed. This new group looks after the energy aspect of operations and energy spending throughout the plant. This is an indication that the management of Brunswick Mining & Smelting is not only conscious of the energy problem, it is also conscious on the savings possible by keeping a tight control on the energy flow throughout the plant.

APPENDIX 'A'

DATA COLLECTION

STARTED AT 102356 ON 1985-03-21

CHANNEL AVG. VALUE CURRENT VALUE

time: 103507 loop

Heat Pump Data

1	TC 1	43	deg. c	ok	65	source w.to h.ex.	95.6	gpm-swhe	[illegible]
2	TC 2	34	deg. c	ok	66	source w.to hp#1	56	gpm-swhp	[illegible]
3	TC 3	44	deg. c	ok	67	source w.to hp#2	1	gpm-swhp	ok
4	TC 4	37	deg. c	ok	68	make-up water flow	25.6	gpm-muw	ok
5	TC 5	0	deg. c	ok	69	not used	2.5	no units	ok
6	TC 6	37	deg. c	ok	70	heat pump#1(power)	0	kw-ph601	[illegible]
7	TC 7	36	deg. c	ok	71	heat pump#2(power)	22.3	kw-ph602	ok
8	TC 8	55	deg. c	ok	72	circulating pump h.ex.	7	kw-ph603	ok
9	TC 9	54	deg. c	ok	73	circulating pump	3.3	kw-ph604	ok
10	TC 10	32	deg. c	ok	74	make-up water pump	3.8	kw-pw616	ok
11	TC 11	33	deg. c	ok	75	source water input	-19600.5	btu/m l	
12	TC 12	28	deg. c	ok	76	make-up water in	547.6	btu/m	
13	TC 13	25	deg. c	ok	77	m-u w heat ex. out	20523.6	btu/m g	
14	TC 14	20	deg. c	ok	78	m-u w heat pump #1	-534.4	btu/m g	
15	TC 15	26	deg. c	ok	79	m-u w heat pump #2	10835	btu/m g	
16	TC 16	37	deg. c	ok	80	condensate return	0	btu/m	
17	TC 17	87	deg. c	ok	81	cop heat exchanger	51.4		
18	TC 18	52	deg. c	ok	82	cop heat pump #1	-5.6		
19	TC 19	38	deg. c	ok	83	cop heat pump #2	7.9		
20	TC 20	88	deg. c	ok	84	cop total	16.6		
21	TC 21	50	deg. c	ok	85	total gain m-u water	28966.3	btu/m	

1983

	WATER															KWH					NOTES
			SOFTENED WATER							SOURCE WATER											
							OUTLET TEMPERATURE							OUTLET TEMPERATURE							
DATE (APRIL)	TIME	FLOW TOTAL	AVERAGE FLOW G.P.M	ACTUAL FLOW G.P.M	TEMPERATURE	HEAT EXCH.	HEAT PUMP 1	HEAT PUMP 2	HEAT EXCH FLOW TOTAL	HEAT PUMP #1 FLOW TOTAL	HEAT PUMP #2 FLOW TOTAL	TEMPERATURE	HEAT EXCH	HEAT PUMP 1	HEAT PUMP 2	PHG01	HEAT PUMP #1 PHG02	HEAT PUMP #2 PHG03	CIRC. TO H. EXCH PHG04	CIRC TO H. PUMP PWG16	CIRC TO BOILER
5	10:15	233970	17.2	20	3.5	35	35	54.5		935690	020510	39.2	31.2	39.2	35	03804	13852	08676	05466	18049	
6	14:30	262420	16.8	21	4.2	36.5	36.5	54.6		954520	136790	40.8	32	40.8	36.5	03915	14465	08881	05562	18195	
7	14:10	287390	16.9	20	(4.0) 7.0	35	44	61.5		971120	238900	39	30.6	26.5	35.2	03931	15057	09060	05647	18322	
8	13:45	310462	17.0	20	(3.5)	40.5	40.5	62		987100	332400	44.8	34.5	44.8	40.0	03982	15617	09223	05724	18438	
11	15:20	384010	16.7	24	(2.8)	33.8	33.8	50.2		039000	635450	40.3	29	40.3	35.5	04145	17447	09758	05979	18823	
12	13:30	407600	17.7	21	(4.0) 5.5	18	18	32		054480	726470	20.0	16.5	20.0	17	04193	17960	09929	06055	18938	
13	14:00	432689	17.1	20	(3.8) 10.0	(35) 35.5	(44.5) 44	(63.7) 61.5		070903	827200	39.5	33	27.0	35.5	04196	18517	10097	06140	19066	
14	15:30	458180	16.6	18	(3.7) 10.0	37.0	37.0	56.8		088375	932300	40.5	33	40.5	36.3	04388	19165	10283	06228	19200	
15	15:35	480125	15.2	21	4.3	27.5	27.5	44.3		104150	030985	32.4	25	32.4	28.3	04395	19724	10457	06310	19324	
19	13:30	565600	15.2	18	(4.0) 4.7	9.7	6.2	10.0		147849	333979	8.2	7.3	8.9	8.5	04974	20916	11144	06558	19815	[illegible]
20	15:30	587575	14.1	14	(4.5) 13.5	18.5	26.7	40		153480	340400	19	16.3	17	16	04977	20920	11314	06562	19941	[illegible]
21	15:00	608410	14.8	20	4.5 5.5	17.5	23.8	36.0		186712	435030	20	16.7	11.5	17.0	05188	21318	11488	06647	20064	[illegible]
22	14:55	629113	14.4	17	(5.5) 10.0	20.5	-	-		203226	532525	22.5	19.8	22.5	22.5	05385	21704	11675	06730	20188	[illegible]

Table 2-1

Ch.	Id.	Descriptions	DEC TC-8
1	TC 1	Source Water Temp. - Input	
2	TC 2	Source Water Temp. - Heat Exchanger Output	
3	TC 3	Source Water Temp. - Heat Pump #1, Evaporator Output	
4	TC 4	Source Water Temp. - Heat Pump #2, Evaporator Output	
5	TC 5	Make-up Water Temp. - Heat Exchanger Input	
6	TC 6	Make-up Water Temp. - Heat Pump #1, Condenser Input	
7	TC 7	Make-up Water Temp. - Heat Pump #2, Condenser Input	
8	TC 8	Make-up Water Temp. - Heat Pump #2, Condenser Output	
9	TC 9	Make-up Water Temp. - To Boiler Room	
10	TC 10	Refrigerant Temp., Evaporator #1, Heat Pump #1	
11	TC 11	Refrigerant Temp., Compressor #1, (To Condenser #1) Heat Pump #1	
12	TC 12	Refrigerant Temp., Condenser #1, Heat Pump #1	
13	TC 13	Refrigerant Temp., Evaporator #2, Heat Pump #1	
14	TC 14	Refrigerant Temp., Compressor #2, (To Condenser #2) Heat Pump #1	
15	TC 15	Refrigerant Temp., Condenser #2, Heat Pump #1	
16	TC 16	Refrigerant Temp., Evaporator #1, Heat Pump #2	
17	TC 17	Refrigerant Temp., Compressor #1, (To Condenser #1) Heat Pump #2	
18	TC 18	Refrigerant Temp., Condenser #1, Heat Pump #2	
19	TC 19	Refrigerant Temp., Evaporator #2, Heat Pump #2	
20	TC 20	Refrigerant Temp., Compressor #2, (To Compressor #2) Heat Pump #2	
21	TC 21	Refrigerant Temp., Condenser #2, Heat Pump #2	
22	TC 22		
23	TC 23		
24	TC 24		
25	TC 25		
26	TC 26		

Table 2-1 (continued)

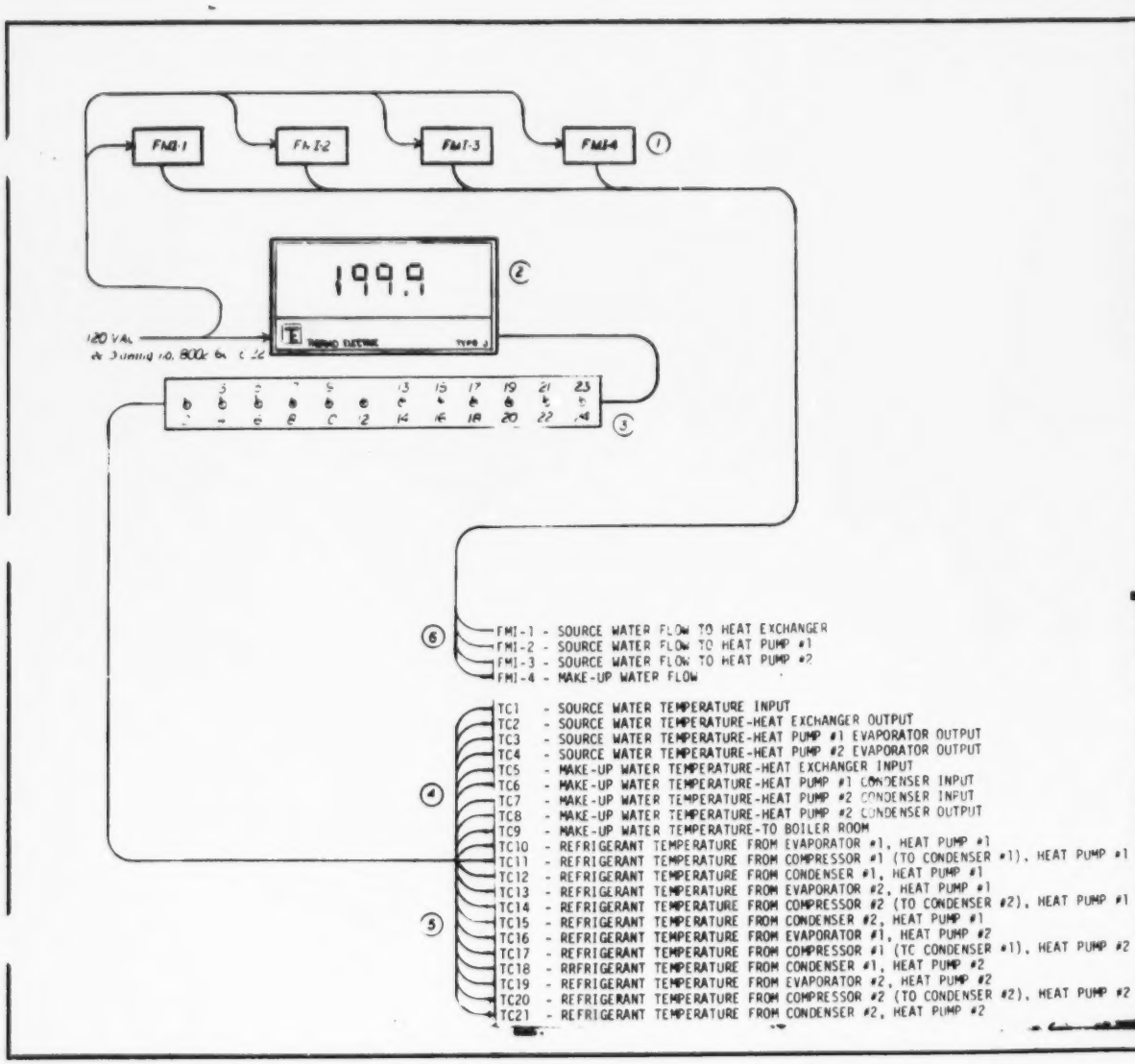
Ch.	Id.	Descriptions			
27	TC 27	Water Jacket, Tap Bay	Temp		
28	TC 28	Water Jacket, # $1B_u$	Temp.		
29	TC 29	Water Jacket, # 2B, IT,Sh	Temp.		
30	TC 30	Mux Panel Compensation	Temp.		
31	TC 31	Water Jacket, # 3B, 2T	Temp.		
32	TC 32	Water Jacket, # 4B, 3T	Temp.		
33	TC 33	Water Jacket, # 5B, 4T	Temp.		
34	TC 34	Water Jacket, # 6B, 5T	Temp.	South	
35	TC 35	Water Jacket, # 7B, 6T	Temp.		
36	TC 36	Water Jacket, # 8B, 7T	Temp.		
37	TC 37	Water Jacket, # 9B, 8T	Temp.		
38	TC 38	Water Jacket, #10B, 9T	Temp.		
39	TC 39	Water Jacket, #11B, 10T	Temp.		
40	TC 40	Water Jacket, #12B, 11T	Temp.		
41	TC 41	Water Jacket, #13B, 12T	Temp.	South	
42	TC 42	Water Jacket, #14B	Temp.	North	
43	TC 43	Water Jacket, #15B, 13T, Sh	Temp.	South	
44	TC 44	Water Jacket, West Input Man, Sh	Temp.		
45	TC 45	Water Jacket, #16B, 14T	Temp.		
46	TC 46	Water Jacket, #17B, 15T	Temp.		
47	TC 47	Water Jacket, #18B, 16T	Temp.		
48	TC 48	Water Jacket, #19B, 17T	Temp.		
49	TC 49	Water Jacket, #20B, 18T	Temp.	North	
50	TC 50	Water Jacket, #21B, 19T	Temp.		
51	TC 51	Water Jacket, #22B, 20T	Temp.		
52	TC 52	Water Jacket, #23B, 21T	Temp.		
53	TC 53	Water Jacket, #24B, 22T	Temp.		
54	TC 54	Water Jacket, #25B, 23T	Temp.		
55	TC 55	Water Jacket, #$1B_L$	Temp.		
56	TC 56	Water Jacket, R.T.Horseshoe North	Temp.		

Table 2-1 (continued)

Ch.	Id.	Descriptions	
57	TC 57	Water Jacket, R.T.Horseshoe South	Temp.
58	TC 58	Water Jacket, R.T. V-Notch North	Temp.
59	TC 59	Water Jacket, R.T. V-Notch South	Temp.
60	TC 60	Water Jacket, Forehearth (3)	Temp.
61	TC 61	Water Jacket, Roy Tapper North	Temp.
62	TC 62	Water Jacket, #26B, 24T	Temp.
63	TC 63	Water Jacket, Slag launder	Temp.
64	TC 64	Water Jacket, Roy Tapper South	Temp.
65	FM 1	Source Water to Heat Exchanger	Flow
66	FM 2	Source Water to Heat Pump #1	Flow
67	FM 3	Source Water to Heat Pump #2	Flow
68	FM 4	Make-up Water	Flow
69	FM 5	Condensate Return Water	Flow
70	KW	Heat Pump #1	Power
71	KW	Heat Pump #2	Power
72	KW	Circulating Pump H E	Power
73	KW	Circulating Pump, Heat Pumps	Power
74	KW	Make-up Water Pump	Power
75	#1 BTU/M L	Source Water Input	Total
76	#2 BTU/M	Make-up Water In	
77	#3 BTU/M G	Make-up Water Heat Exchanger Output	
78	# 4 BTU/M G	Make-up Water Heat Pump, #1	
79	# 5 BTU/M G	Make-up Water Heat Pump, #2	
80	# 6 BTU/M	Condensate Return	
81	# 7 COP	Heat Exchanger	
82	# 8 COP	Heat Pump #1	
83	# 9 COP	Heat Pump #2	
84	#10 COP	Total	
85	#11 BTU/M	Total gain Make-up Water	
86			
87			
88			

APPENDIX 'B'

PIPING AND INSTRUMENTATION DRAWING



REFERENCE DRAWINGS

NUMBER	TITLE
8002-60-0003	P&I DIAGRAM
8002-60-6123	ELECTRICAL PANEL LAYOUT

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION
1	4	Flowmeter remote indicator
2	1	ELPH3 Temperature indicator
3	1	24-Position Rep switch Module
4	9	Thermocouple 11484-P-J-4'8-14-S
5	12	" 2J2131 A
6	4	Flowmeters with impulse switches

NOTES:

1. Refer to P&I. Diagram for Thermocouple and flowmeter locations.
2. ( ) denotes item numbers

DESCRIPTION	NO.	DATE	BY
ISSUED FOR CONSTRUCTION	1	7/9/82	DJD
ISSUED FOR APPROVAL	A	26/8/82	DJD

REVISIONS TO DRAWING

DESIGNED D DOYLE	DRAWN D DOYLE
CHECKED	APPROVED
DATE 26-8-82	SHEET 1 OF

BRUNSWICK MINING AND SMELTING CORP. LTD.
SMELTING DIVISION
BELLEDUNE N.B.

DRAWING TITLE
HEAT PUMP INSTALLATION INSTRUMENTATION

DWG. NO. 8002-60-SK3 REV NO 1

APPENDIX 'C'

DESCRIPTION OF EQUIPMENT

Qantity	Equipment	Description
1.	Westinghouse Templifier Heat Pump Water Heater Model TPB - 025A	25 tons capacity heat pump power supply 600 volts - refrigirant: R-500 Max Hot Water Temp : 57°C Compressor : Two full hermetic Condenser : Two in series flow Evaporator : Two in series flow High Pressure cut out: 300 psig.
1.	Westinghouse Templifier Heat Pump Water Heater Model TPB-025B	Capacity : 25 tons Power Supply : 600 volts Refrigirant : R-12 Max Hot Water Temp : 71°C Compressor : Two full Hermetic Condenser : Two in series flow Evaporator : Two in series flow High Pressure cut out: ~~300~~ 360 psig.
1.	Alpha Laval Plate Heat Exchanger Type P22-VL	Design Temp. : 110°C Design Press.: 100 psig Test Press. : 150 psig Heating Surface : 58.1 sq ft

DESCRIPTION OF EQUIPMENT

Quantity	Equipment	Description
1. Cont'd		No. of Plates : 45 (type P22x0.6mm) 100 plates capacity Plates Material : A.I.S.I. Stainless Steel.
3.	Aurora Pump	Make up Water Pump (Existing) Motor 600 volts General Electric 7½HP Impeller Size : RPM : 1750 Max Outlet Pressure : 150 psig Capacity : Source Water Pump to Heat Exchanger: Motor 600 volts General Electric 7½HP Impeller Size : 11 1/4 inches R.P.M. : 1750 Max Outlet Pressure: 67 psi Capacity: 108 USGPM @ 140 ft. TDH Source Water Pump to Heat Pump Motor 600 volts General Electric 5HP Impeller Size : 8 in. R.P.M. : 1750 Max Outlet Pressure : 31 psi Capacity: 200 usgph @ 75 ft. TDH

DESCRIPTION OF EQUIPMENT

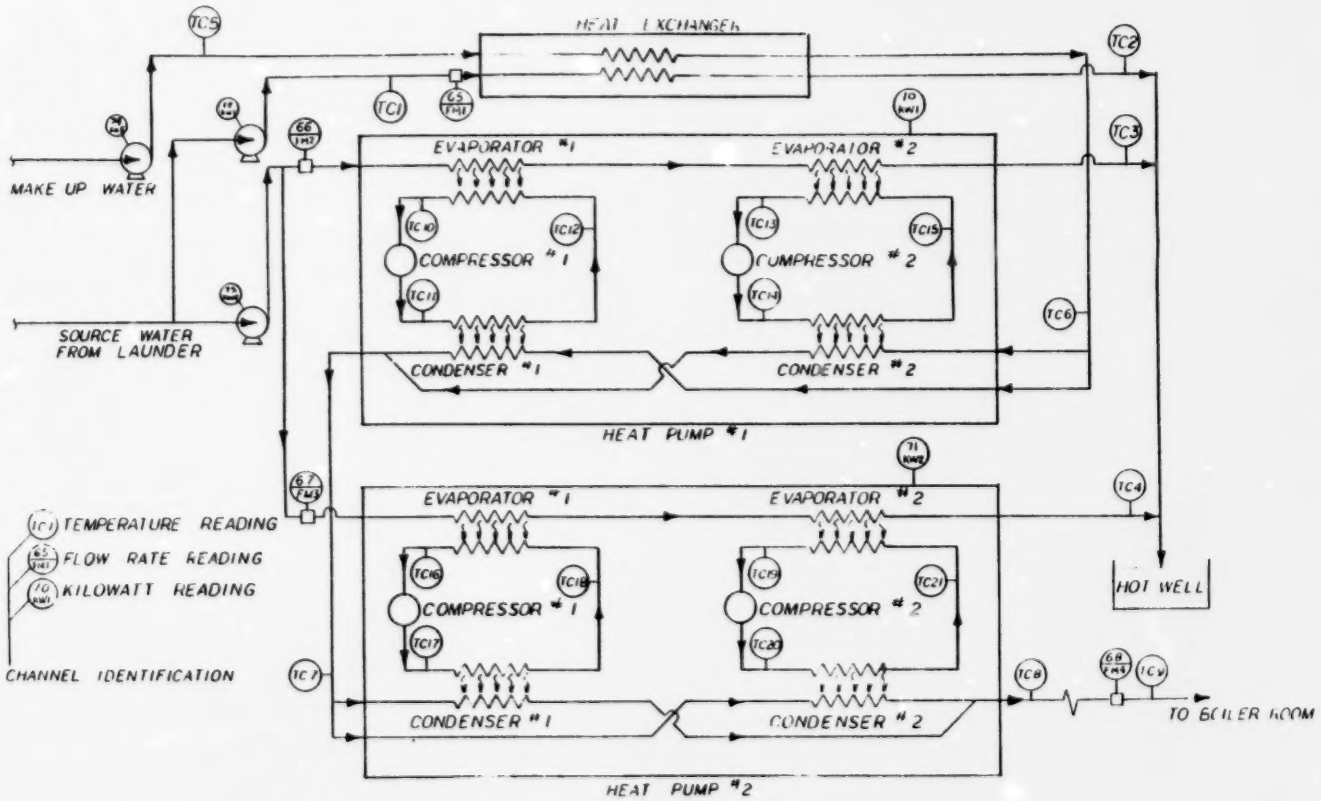
Quantity	Equipment	Description
4.	Neptune Flow Meters	Source Water Lines 2" Green seal meters with Model 157 Register and Impulse switches with remote readouts. Make up Water Line 1½" Green seal meters with Model 157 Register and Impulse switches with remote readouts.
4.	Watthour Meter	Sangamo Kys 100A,600V, 2 element Cat. No. 902424
21	Thermocouples	J-Type Thermocouple.
2	Normally Open Solenoid Valve	ASCO 1½" Cat. No. 8210D32
1	Normally Closed Solenoid Valve	ASCO 1½" Cat. No. 8210D22

DESCRIPTION OF EQUIPMENT

Quantity	Equipment	Description
1.	Temperature Meter	Digital Temperature Meter from Thermo Electric Canada, ELPH 3, J. Thermocouple, DEG. C. 1/10 DEG. C Resolution.

APPENDIX 'D'

MONITORING POINTS OF HEAT PUMPS SYSTEM



APPENDIX 'E'

START-UP

THE FOLLOWING IS A LIST OF THE STEPS, WITH DESCRIPTIONS THAT WERE FOLLOWED IN PREPARATION FOR START-UP AND DURING START-UP.

A) WATER LEAKS SURVEY

i) THE TWO CIRCULATOR PUMPS ON THE SOURCE WATER SIDE WERE PUT ON LINE AND THE SYSTEM PRESSURIZED TO ITS OPERATING CONDITIONS. ALL LEAKS WERE REPAIRED.

ii) THE VALVES WERE OPENED ON THE CONDENSER SIDE TO LET THE FLOW OF RAW, SOFTENED WATER FILL THE SYSTEM. THE PRESSURE WAS RAISED TO THE MAXIMUM OPERATING PRESSURE OF 150 P.S.I. ALL APPARENT LEAKS WERE ELIMINATED.

B) WATER FLOW SURVEY

i) EVAPORATOR SIDE:

WITH THE TWO CIRCULATOR PUMPS ON LINE, THE FLOW WAS READ OFF THE NEPTUNE FLOW METER IN EACH LINE. FLOW METER NO.3, BEFORE HEAT PUMP NO.2 WAS MALFUNCTIONNING THEREFORE WE BASED OUR CALCULATIONS ON THE READING OF FLOW METER NO. 2 BEFORE HEAT PUMP NO. I. THESE TWO FLOWS WERE FURTHER VERIFIED AND PROVED TO BE NEARLY IDENTICAL.

i) EVAPORATOR SIDE: (Cont'd)

FOR THE FLOW THROUGH THE PLATE HEAT EXCHANGER, THE READING OFF FLOW METER NO. 1 WAS VERIFIED. IN EACH CASE ONLY ABOUT 50% OF THE DESIGN FLOW WAS AVAILABLE, FROM THE READINGS OF THE PRESSURE GAUGES AT THE OUTLET OF EACH CIRCULATOR PUMP IT WAS CONCLUDED THAT THERE WAS EXCESSIVE SUCTION HEAD ON THE PUMP. IT WAS THEN DECIDED TO RAISE THE WATER LEVEL IN THE LAUNDER TO REDUCE THE SUCTION HEAD. THIS WAS MADE POSSIBLE BY INSTALLING A WEIR IN THE LAUNDER BEFORE THE MAIN 6" DIAMETER OUTLET AT THE BOTTOM OF THE LAUNDER. THIS EFFECTIVELY RESOLVES THE PROBLEM.

THE FLOW READINGS ON FLOW METER NO. 2 AND FLOW METER NO. 3 ARE NOW 295 L/MIN. AND 290 L/MIN. RESPECTIVELY. THESE FLOWS ARE ACCEPTABLE COMPARED WITH THE DESIGN FLOWS OF 303 L/MIN. THE FLOW READING ON FLOW METER NO. 4 IS NOW 450 L/MIN. THIS FLOW IS WELL OVER THE DESIGN FIGURE OF 350 L/MIN. THE REASON FOR THIS BEING THE PIPING TO THE HEAT EXCHANGER HAD BEEN SIMPLIFIED AND PRESSURE REDUCTION ON THE PUMP OUTLET RESULTED IN AN INCREASE IN FLOW.

ii) CONDENSER SIDE:

WITH ALL VALVES ON THE CONDENSER SIDE THE PRESSURE WAS RAISED TO 150 P.S.I. WITH THE AID OF THE BOILER MAKE UP BOOSTER PUMP. THE BOILER WAS SET ON A BLOW DOWN CYCLE SO AS TO INCREASE THE DEMAND OF MAKE UP WATER. THE FLOW WAS INCREASED TO 80 L/MIN.

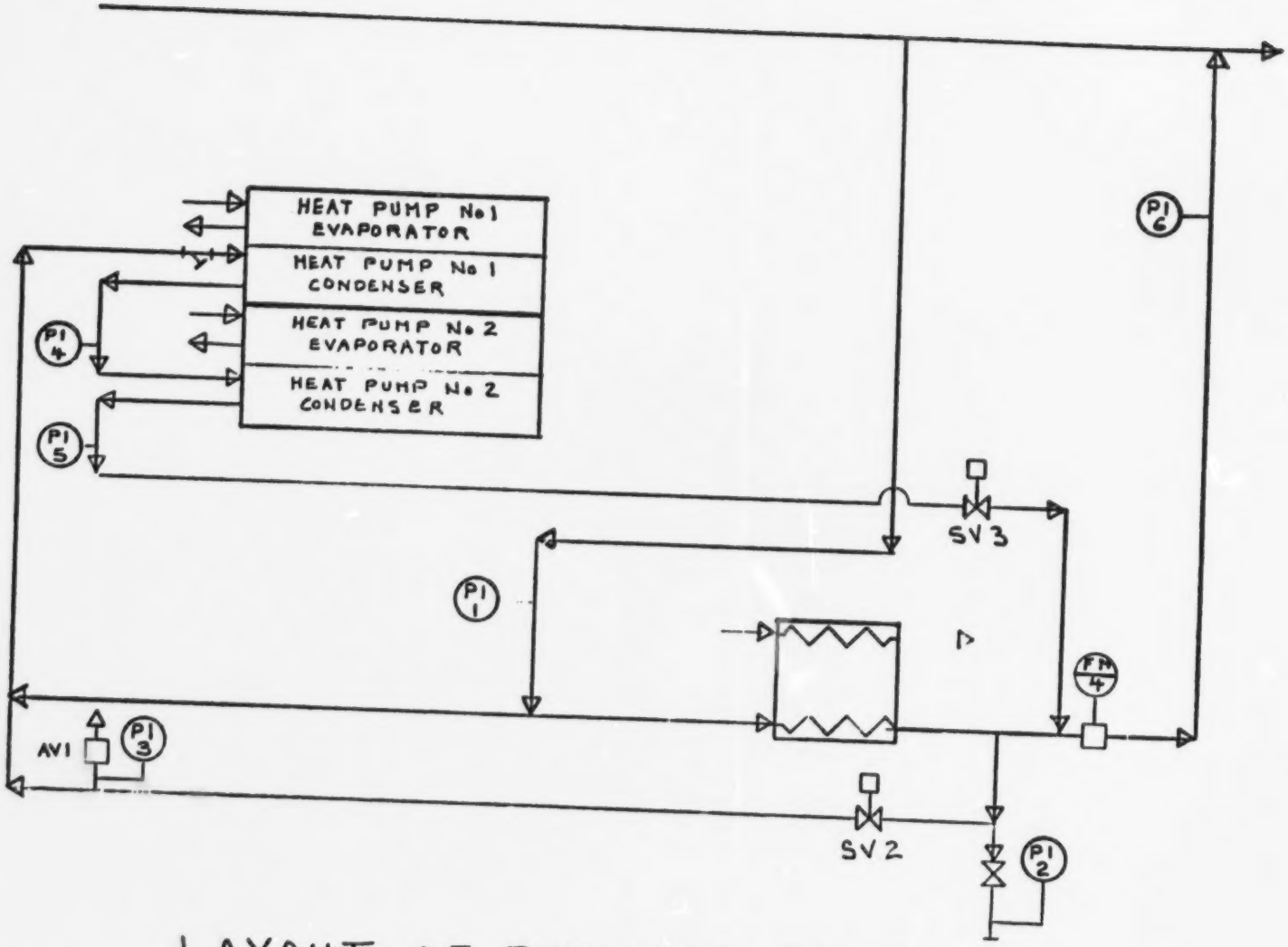
ii) CONDENSER SIDE: (Cont'd)

WHICH RESULTED IN A DRASTIC PRESSURE DROP OF 120 PSI ACROSS THE SYSTEM. THERE WAS DEFINITELY AN OBSTRUCTION IN THE LINE. TO LOCATE THIS OBSTRUCTION, PRESSURE GAUGES WERE INSTALLED AT ALL STRATEGIC POINTS IN THE SYSTEM. THE DRAIN POINTS WERE UTILIZED FOR THIS PURPOSE. FIGURE I GIVES A SCHEMATIC ILLUSTRATION OF THESE POINTS.

THE CAUSE OF THE PRESSURE DROP WAS EVENTUALLY LOCATED BETWEEN THE OUTLET OF THE HEAT EXCHANGER (AFTER SOLENOID VALVE SV2) AND THE OUTLET OF HEAT PUMP NO. I (BETWEEN PI 3 AND PI 4 ON FIGURE I). THE STRAINER LOCATED BETWEEN THOSE TWO POINTS WAS CHECKED AND FOUND TO BE CLEAN. NEVERTHELESS THE OPENING OF THE STRAINER DID RESOLVE THE PROBLEM. IT WAS CONCLUDED THAT AN AIR POCKET MAY HAVE BEEN DISLODGE WHEN THE STRAINER WAS OPEN WITH THE PRESSURE STILL ON THE LINE. IT WAS LATER DISCOVERED THAT ONE AUTOMATIC AIR RELEASE VALVE WAS MALFUNCTIONING.

THE PRESSURE DROP WAS CHECKED AGAIN AFTER THE ELIMINATION OF THE OBSTRUCTION IN THE SYSTEM. TABLE 2 LISTS THE PRESSURE DROPS ON GAUGES 1 TO 6 FOR VARIOUS FLOWS.

AGAIN REFER TO FIGURE 1 FOR ILLUSTRATION OF THE PRESSURE POINTS.



LAYOUT OF PRESSURE POINTS
FIGURE 1

TABLE 2

PRESSURE READINGS AT VARIOUS FLOW (P.S.I.)

Gauge No.	FLOWS (L/MIN)			
	70	90	110	GAUGE ELEVATION RELATIVE TO FLOOR (FT.)
PI I	60	58	55	9
PI 2	63	60	56	2
PI 3	57	51	56	9
PI 4	56	50	46	2
PI 5	56	49	44	2
PI 6	51	44	39	4

N.B. THE ACTUAL FLOW MAY SLIGHTLY DIFFER FROM THE MARKED VALUES SINCE THERE WAS SOME VARIATION IN FLOWS DURING THE TIME IT TOOK TO READ ALL THE GAUGES.

CONDENSER SIDE: (Cont'd)

IT IS INTERESTING TO NOTE THAT THE MOST SIGNIFICANT PRESSURE DROPS ARE LOCATED ACROSS THE SOLENOID VALVES.

C) TEMPERATURE SURVEYS:

APPENDIX "B" CONTAINS A LAYOUT ENTITLED "HEAT PUMP INSTALLATION INSTRUMENTATION" ON DRAWING NO.8002-60-SK3. THIS LAYOUT ILLUSTRATES THE INSTRUMENT PANEL WITH THE DESCRIPTION OF EACH READOUT.

SINCE THE HEAT PUMPS WERE OPERATED FOR A SHORT PERIOD ONLY, THERE HAS BEEN NO TIME TO MONITOR THE TEMPERATURES AT ALL POINTS IN THE SYSTEM.

ON START-UP OF THE HEAT PUMPS, THE FLOW OF WATER THROUGH THE CONDENSERS WAS AVERAGING 90 L/MIN. THE INLET TEMPERATURE TO THE HEAT EXCHANGER WAS 3°C AND THE OUTLET WAS 31°C. THE TEMPERATURE OF THE COOLING WATER FROM THE FURNACE THAT DAY WAS 34°C INSTEAD OF 41°C ANTICIPATED IN THE DESIGN. AS A RESULT THE ENTERING WATER TO HEAT PUMP NO. I WAS AT 31°C AND THE OUTLET FROM HEAT PUMP NO. 2 WAS 69°C. THE TEMPERATURE AT THE OTHER POINTS WERE NOT RECORDED DUE TO THE CONSTANT TRIPPING OF THE HEAT PUMPS ON HIGH PRESSURE.

D) REVIEW OF CONCEPT

IN TRYING TO DESCRIBE THE CAUSE OF THESE FAILURES IT MAY BE NECESSARY TO REFER TO THE ORIGINAL CONCEPT. IT WAS ANTICIPATED IN THE DESIGN STAGE THAT THE FLOW THROUGH THE CONDENSER WOULD VARY AND THAT THE ONLY CONTROL ON THIS FLOW WAS THE FLOAT VALVE IN THE DEAERATOR AT THE BOILER HOUSE. SINCE THIS FLOW WAS TO BE MODULATED ACCORDING TO THE LEVEL IN THE DEAERATOR TANK, IT WAS EXPECTED THAT THE THERMOSTATS ON THE HEAT PUMPS WOULD REACT TO THESE SLOW VARIATIONS IN FLOW, DUE TO A RISE IN THE OUTLET WATER TEMPERATURE.

WHAT WAS DISCOVERED IN THE EARLY STAGE OF DESIGN WAS THAT THE THERMOSTATS WERE INSTALLED BY THE MANUFACTURER AT THE CONDENSER INLETS AND NOT AT THE OUTLETS AS EXPECTED. THIS CREATED A PROBLEM SINCE THE TEMPERATURE AT THE INLET TO HEAT PUMP NO. I WAS CONSTANT AND ANY VARIATIONS IN FLOW RESULTING IN A HIGHER OUTLET TEMPERATURE COULD NOT BE PICKED UP BY THE THERMOSTAT. AFTER CONSULTATION WITH MCQUAY ENGINEERS IT WAS DECIDED TO INSTALL PRESSURE CONTROL VALVES IN THE SOURCE WATER LINE TO EACH HEAT PUMP. THOSE VALVES WERE TO BE CONTROLED BY THE PRESSURE IN THE CONDENSER SUCH THAT A HIGH PRESSURE WOULD CLOSE THE VALVES AND THEREFORE REDUCE THE FLOW OF SOURCE WATER TO THE HEAT PUMP EVAPORATORS. THIS IN TURN WOULD REDUCE THE EFFICIENCY OF THE HEAT PUMPS AND ALLOW THEN TO OPERATE AT LOWER WATER FLOWS THROUGH THE CONDENSERS.

E) MODIFICATION TO SYSTEM

ON START UP, THE MCGUAY REPRESENTATIVE THOUGHT THAT HE COULD RESOLVE THE PROBLEM DUE TO VARIATION OF FLOW, BY RELOCATING THE THERMOSTATS AT THE CONDENSERS OUTLETS INSTEAD OF THE INLETS. IF THAT COULD BE DONE, THAN IT WOULD BE POSSIBLE TO DO AWAY WITH THE PRESSURE CONTROLLED VALVES WHICH HE THOUGHT WOULD GIVE US TROUBLE APART FROM LOWERING THE EFFICIENCY OF THE HEAT PUMPS.

AFTER A CONFERENCE CALL TO VIRGINIA WITH MCGUAY ENGINEER IT WAS DECIDED TO CHANGE ONE THERMOSTAT ONLY, ON CONDENSER NO. 2 OF HEAT PUMP NO. 1. THIS WAY THE SHORT CYCLING OF THE HEAT PUMP COULD BE PREVENTED. AS FOR HEAT PUMP NO. 2 THE THERMOSTAT ON THE INLET COULD STILL REACT TO A LOW FLOW SINCE THE HIGHER OUTPUT TEMPERATURE FROM NO. 1 HEAT PUMP WOULD BE SENSE BY THE INLET THERMOSTAT.

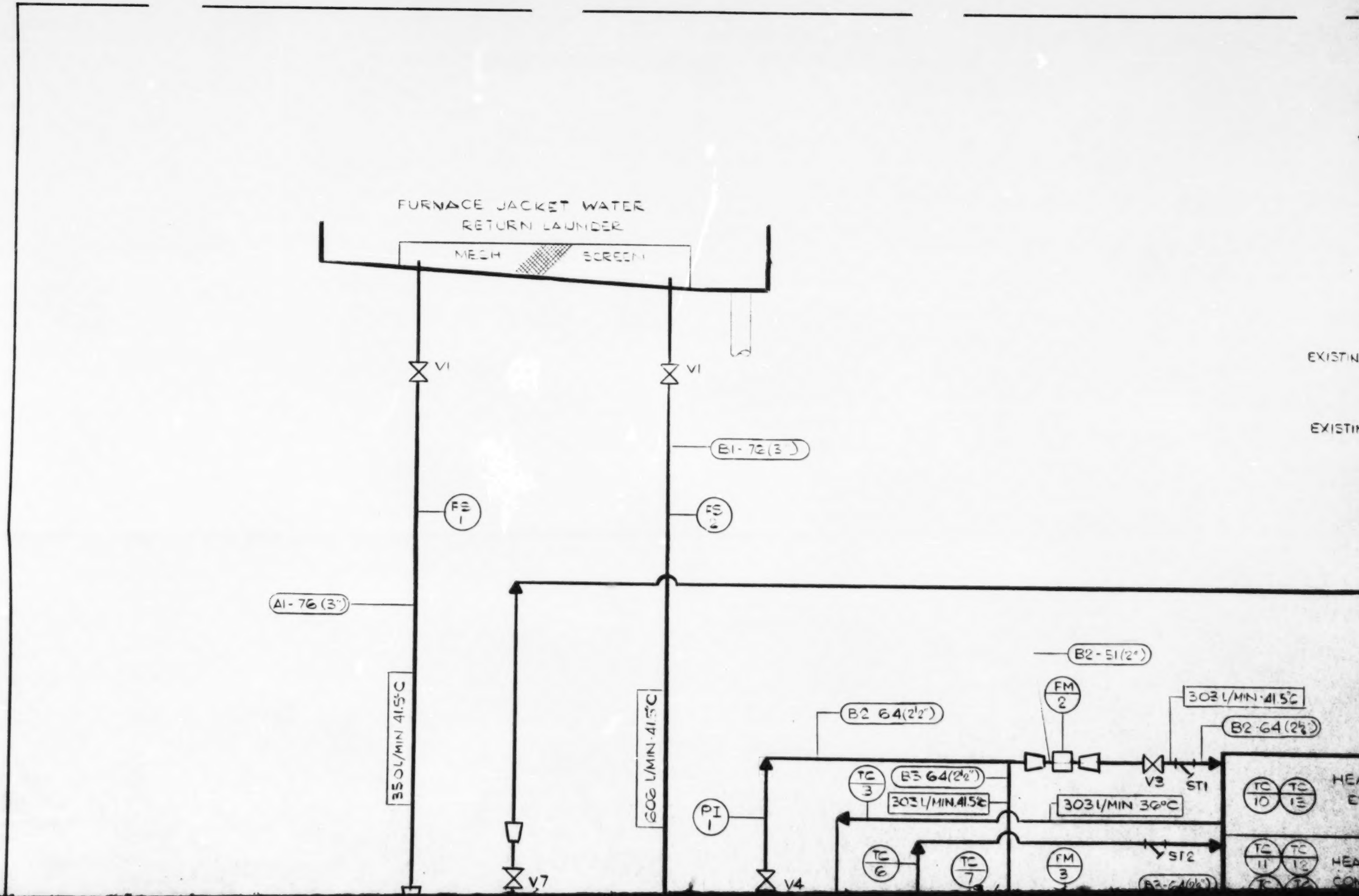
THIS SYSTEM WAS TRIED AND SEEMED TO WORK PERFECTLY UNTIL THE FLOW TO THE HEAT PUMPS CONDENSERS DROPPED INSTANTANEOUSLY. THIS SEVERE DROP IN FLOW DID NOT LEAVE ANY TIME FOR THE THERMOSTAT TO REACT AND THEN ALL COMPRESSERS TRIPPED OUT ON HIGH PRESSURE. A SERIES OF TRIALS DEMONSTRATED THAT THIS WAS HAPPENING AT INTERVALS VARYING FROM TEN TO THIRTY MINUTES. THIS PROBLEM WAS FINALLY ATTRIBUTED TO THE CONDENSATE RETURN SYSTEM TO THE BOILER. THIS SYSTEM IS COMPOSED OF SIX CONDENSATE

MODIFICATION TO SYSTEM (Cont'd)

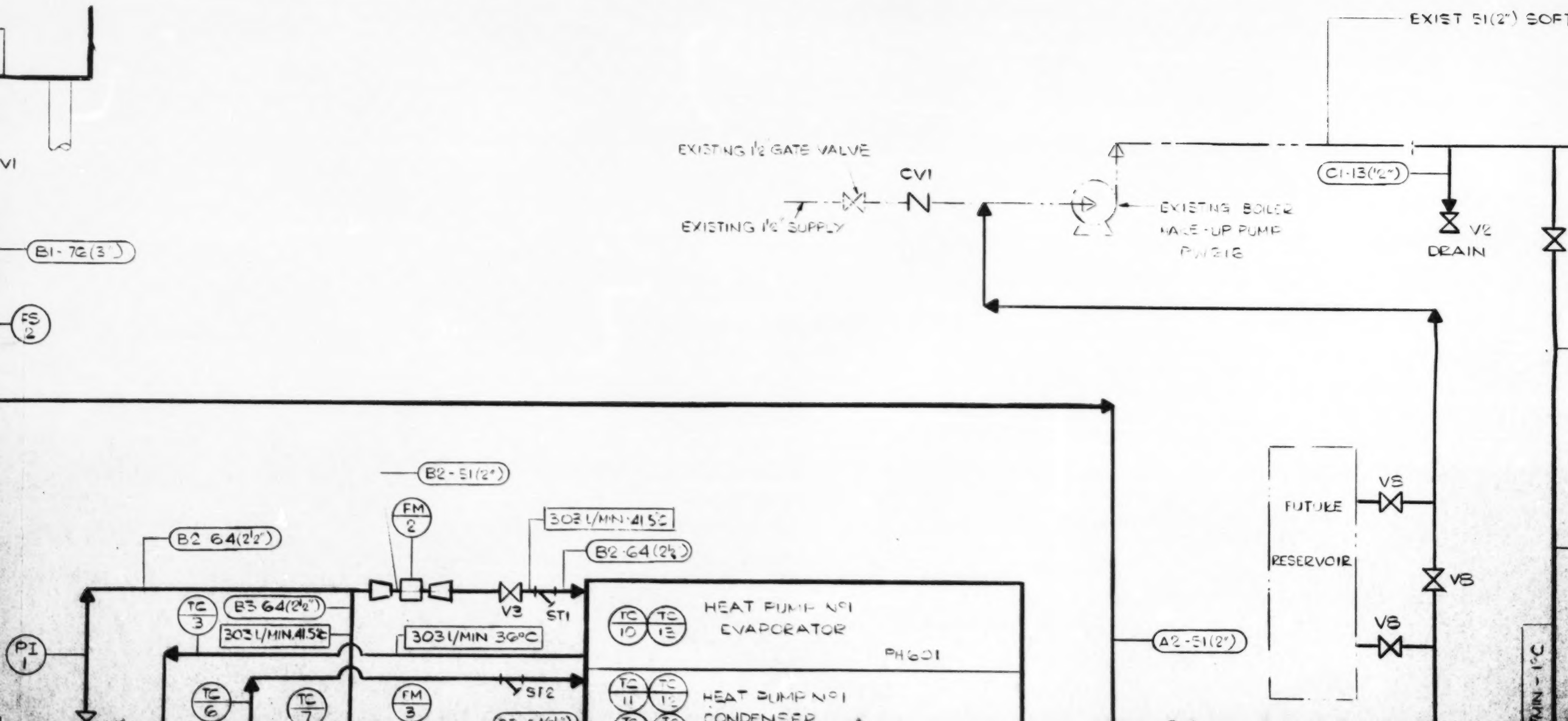
RETURN PUMPS ALL CONTROLLED BY A FLOAT SWITCH IN THE HOLDING TANK ADJACENT TO EACH PUMP. EVERY TIME ONE PUMP STARTS IT CREATES A BACK PRESSURE ON THE WATER MAKE UP LINE FROM THE HEAT PUMP SYSTEM, THIS IN TURN REDUCES THE FLOWS DRASTICALLY DEPENDING ON THE BACK PRESSURE EXERTED. THIS EXCESSIVE FLUCTUATION IN FLOW CANNOT BE TOLERATED BY THE EXISTING SYSTEM.

THE PROPOSED WAY TO SOLVE THIS PROBLEM IS BY THE ADDITION OF A RECIRCULATION LOOP WHICH WILL RAISE THE WATER TEMPERATURE UNTIL IT REACHES THE THERMOSTAT LIMITS. THIS WILL AUTOMATICALLY CONTROL THE FOUR COMPRESSORS IN SEQUENCE DEPENDING ON THE DEMAND.

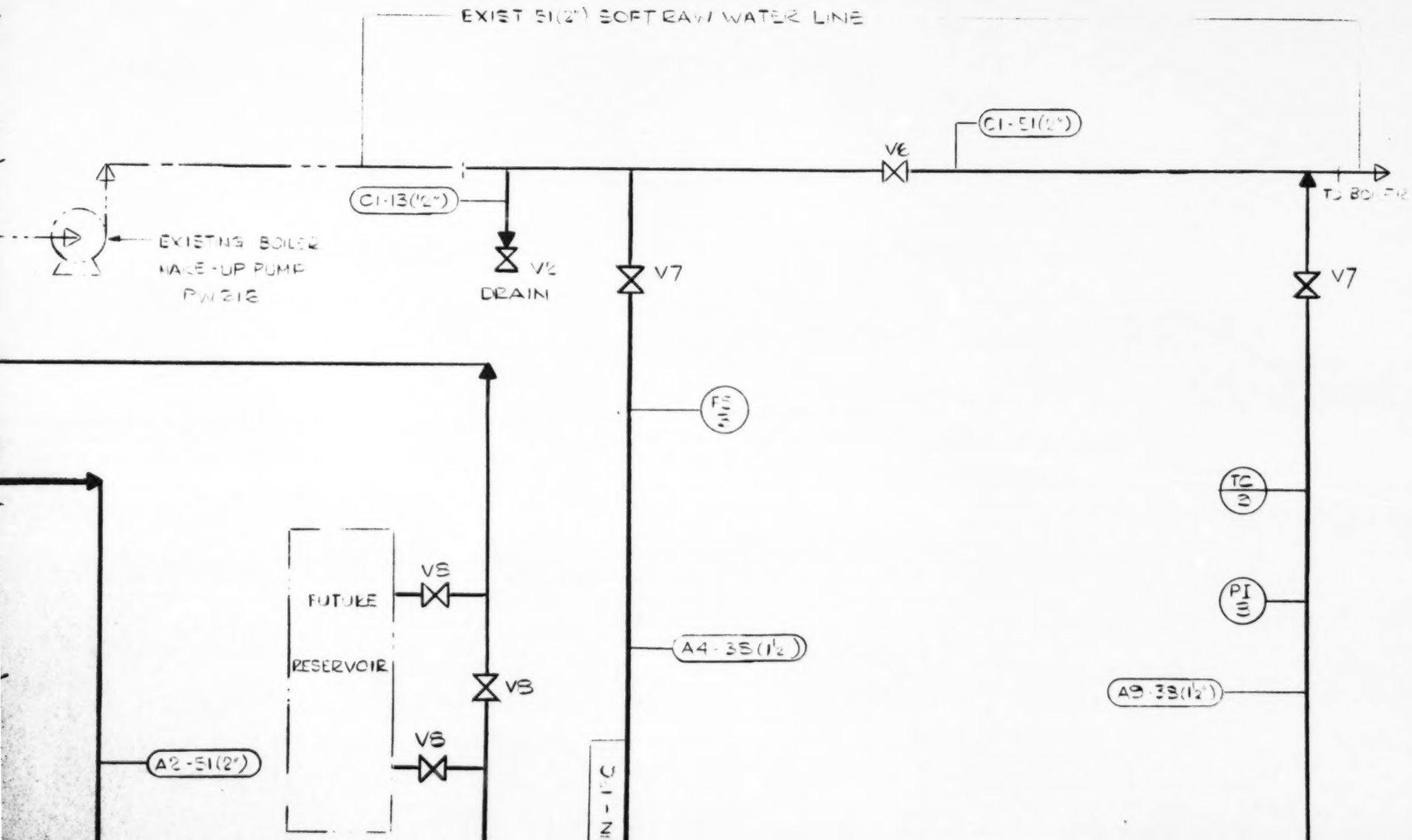
THIS LOOP WILL OPERATE ON THE PRINCIPLE OF PRESSURE DROP THROUGH THE SYSTEM AT DESIGN FLOW. WHEN THE FLOW DROPS, THE PRESSURE AT THE OUTLET OF THE SYSTEM WILL RISE CAUSING A PRESSURE RELIEF VALVE TO OPEN, THEREBY LETTING THE EXCESS WATER RETURN TO THE MAKE UP WATER PUMP SUCTION. THE PRESSURE RELIEF VALVE WILL MODULATE ACCORDING TO THE PRESSURE BUILD UP OVER THE RELIEF SETTING, A SLIGHT INCREASE IN PRESSURE WILL INCREASE THE FLOW THROUGH THE VALVE.



FURNACE JACKET WATER
RETURN LAUNDER
MESH
SCREEN
V1
V1
B1-76(3")
FS 1
FS 2
A1-76(3")
350 L/MIN 41.5°C
606 L/MIN 41.5°C
V7
V4
PI 1
B2-51(2")
FM 2
303 L/MIN 41.5°C
B2 64(2½")
B2-64(2½")
TC 3
B3 64(2½")
303 L/MIN 41.5°C
303 L/MIN 36°C
V3
ST1
TC 10
TC 13
TC 6
TC 7
FM 3
ST2
TC 11
TC 12


EXIST 51(2") SOFT
VI
EXISTING 1½ GATE VALVE
CVI
EXISTING 1½" SUPPLY
EXISTING BOILER
MAKE-UP PUMP
PW318
C1-13(½")
V2
DRAIN
B1-76(3")
FS
2
B2-51(2")
FM
2
303 L/MIN 41.5°C
B2 64(2½")
B2-64(2½")
TC
3
B3 64(2½")
303 L/MIN 41.5°C
V3
ST1
303 L/MIN 36°C
HEAT PUMP Nº1
EVAPORATOR
TC
10
TC
13
PH601
PI
1
TC
6
TC
7
FM
3
ST2
TC
11
TC
12
HEAT PUMP Nº1
CONDENSER
A2-51(2")
FUTURE
RESERVOIR
V5
V8
V8
MIN - 1°C

8002-60-0003



REFERENCE DRAWINGS

NUMBER	TITLE
8002-60-7013	INSTRUMENT DIAGRAM
8002-60-5002	PIPING & EQUIPMENT - SH#1
8002-60-5003	" " SH#2
8002-60-5004	" " SH#3
8002-60-5005	" " - SH#4
8002-60-4001	MISC. STEEL

NOTES:

LEGEND

(A2-51(2")) LINE IDENTIFICATION

[303 L/MIN-40°C] FLOW & TEMPERATURE

(FM 1) LOCAL MOUNTED INSTRUMENTS

(TC 1) PANEL MOUNTED INSTRUMENTS

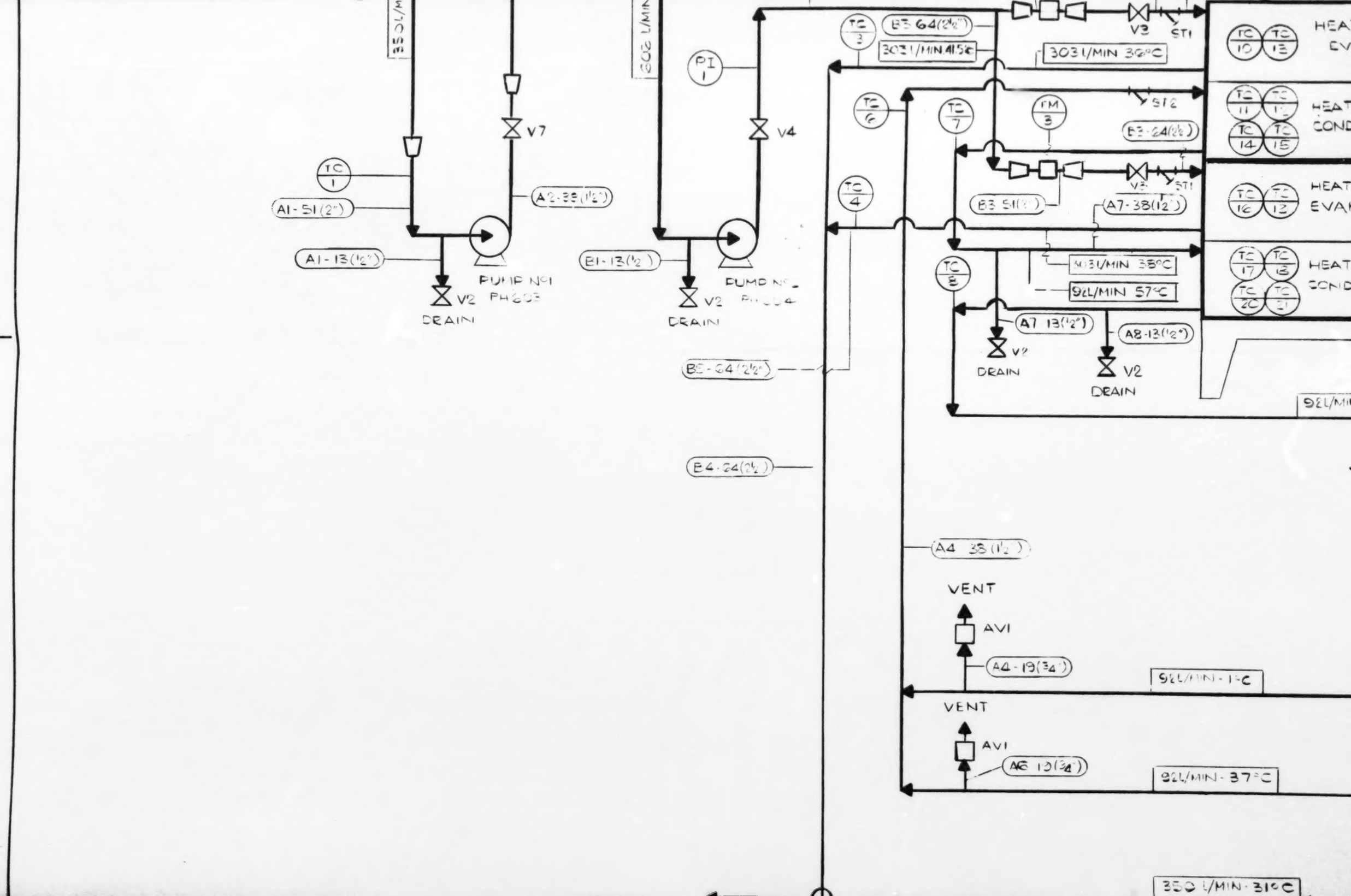
VALVE LIST

V1. 3" CRANE 465½ IRON BODY WEDGE GATE VALVE

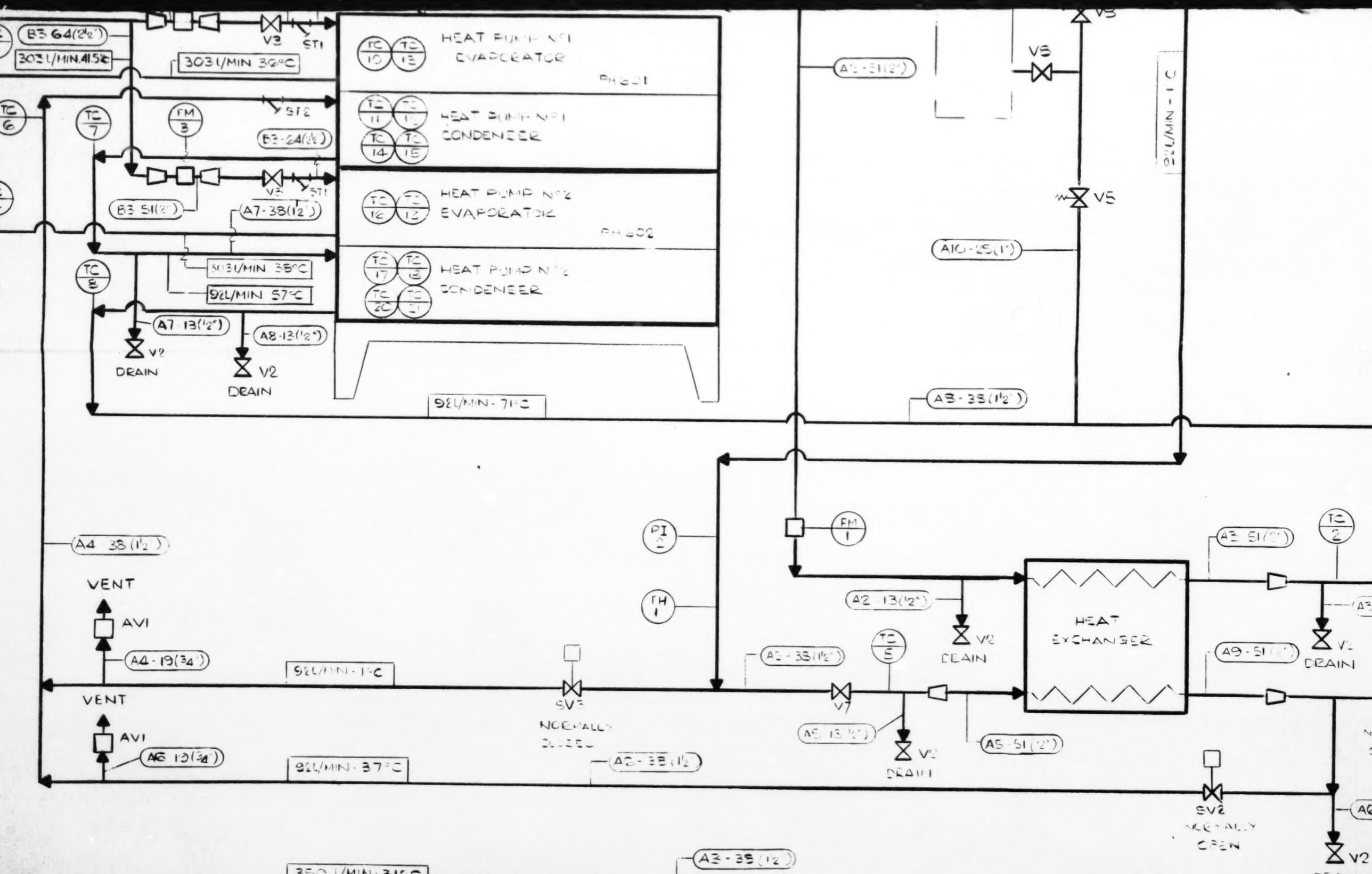
V2 ½" CRANE 438 BRONZE GATE VALVE

V3 2½" CRANE 440 BRONZE GATE VALVE

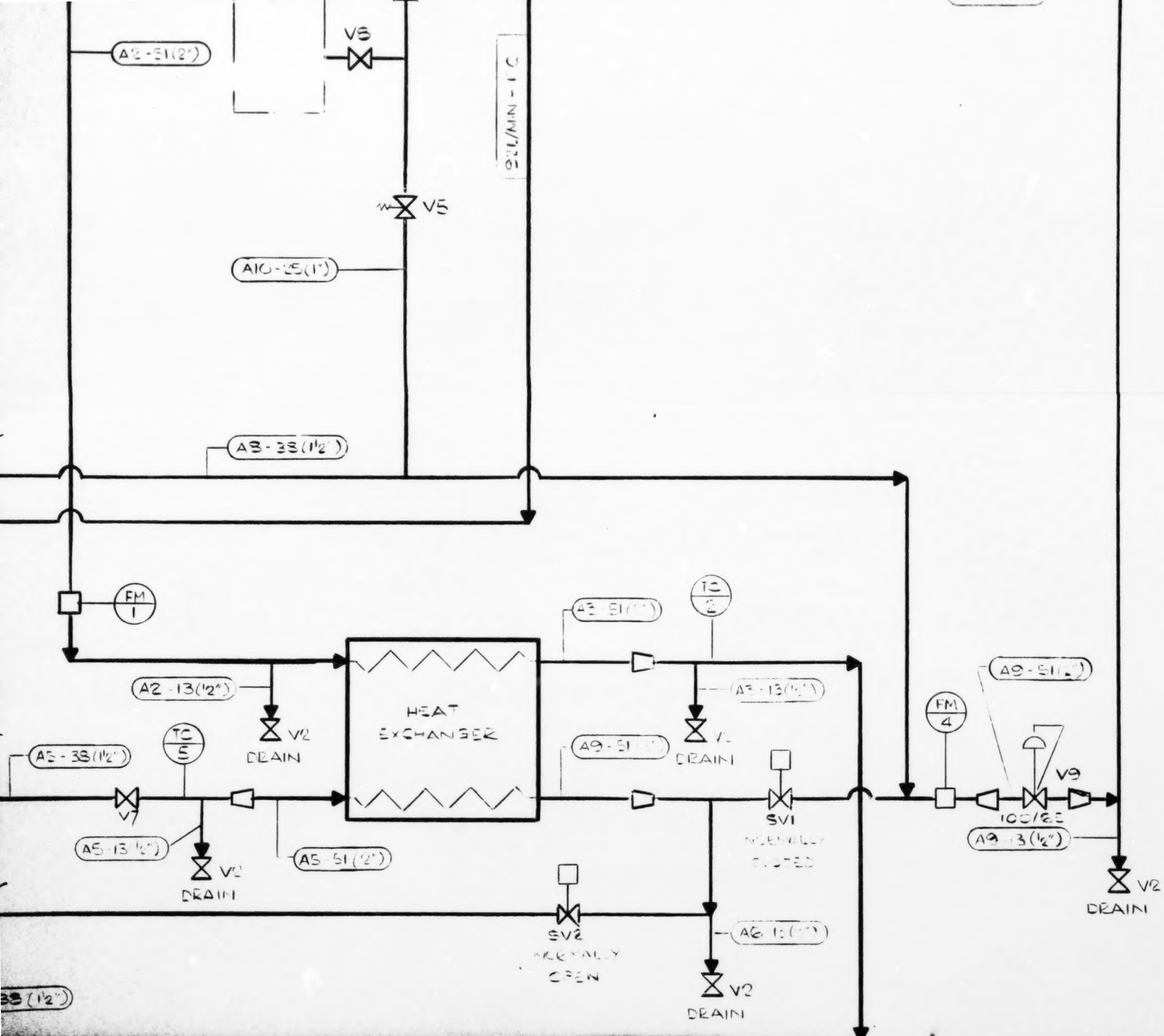
V4 2½" CRANE 465½ WEDGE GATE VALVE



350 L/M
606 L/MIN
TC 1
A1-51(2")
A1-13(1/2")
V7
A2-38(1 1/2")
PUMP No1
PH603
V2
DRAIN
PI 1
V4
B1-13(1/2")
PUMP No2
PH604
V2
DRAIN
TC 3
B3 64(2 1/2")
303 L/MIN 41.5°C
303 L/MIN 36°C
V3
ST1
TC 6
TC 7
FM 3
ST2
B3-64(2 1/2")
TC 4
B3 51(2")
A7-38(1 1/2")
303 L/MIN 38°C
92 L/MIN 57°C
TC 8
A7 13(1/2")
A8-13(1/2")
V2
DRAIN
V2
DRAIN
B5-64(2 1/2")
B4-64(2 1/2")
A4 38(1 1/2")
VENT
AV1
A4-19(3/4")
92 L/MIN-1°C
VENT
AV1
A6 19(3/4")
92 L/MIN-37°C
350 L/MIN-31°C
TC 10
TC 13
TC 11
TC 14
TC 15
TC 16
TC 17
TC 18
TC 20
TC 21



B3 64(2½")
303 L/MIN 41.5°C
303 L/MIN 36°C
V3
ST1
ST2
TC 6
TC 7
FM 3
B3-64(2½")
B3 51(2")
A7-38(1½")
TC 8
303 L/MIN 38°C
92 L/MIN 57°C
A7 13(½")
A8-13(½")
V2
DRAIN
HEAT PUMP No1 EVAPORATOR
PH 601
HEAT PUMP No1 CONDENSER
HEAT PUMP No2 EVAPORATOR
PH 602
HEAT PUMP No2 CONDENSER
92 L/MIN - 71°C
A2-51(2")
V5
A10-25(1")
A8-38(1½")
92 L/MIN - 1°C
A4 38(1½")
VENT
AV1
A4-19(¾")
92 L/MIN - 1°C
SV3
NORMALLY CLOSED
A6 19(¾")
92 L/MIN - 37°C
A8-38(1½")
PI 2
TH 1
FM 1
A2-13(½")
TC 5
A3-38(1½")
V7
A5 13(½")
A5-51(2")
HEAT EXCHANGER
A3-51(2")
TC 2
A9-51(2")
SV2
NORMALLY OPEN
A3-38(1½")



V1. 3 CRANE 430 IRON BODY WEDGE GATE VALVE
V2 ½ CRANE 438 BRONZE GATE VALVE
V3 ½ CRANE 440 BRONZE GATE VALVE
V4 2½ CRANE 438 ½ WEDGE GATE VALVE
V5 1" FISHER PRESSURE REDUCING VALVE TYPE 98H SETTING 100 PSIG.
V6 ½ CRANE 438 BRONZE GATE VALVE
V7 1½ CRANE 438 BRONZE GATE VALVE
SV1 1½ ASCO 3 WAY SOLENOID VALVE - NORMALLY CLOSED CAT # 8210 D62
SV2 SVE 1½ ASCO 3 WAY SOLENOID VALVE - NORMALLY OPEN CAT # 8210 D 82
ST1 2½ SALCO TYPE SE STRAINER STD SCREEN
ST2 1½ SALCO TYPE SE STRAINER STD SCREEN
AV1 ¾ INLET SALCO TYPE AWN 150 FLOAT TYPE AIR VENT.

INSTRUMENTS

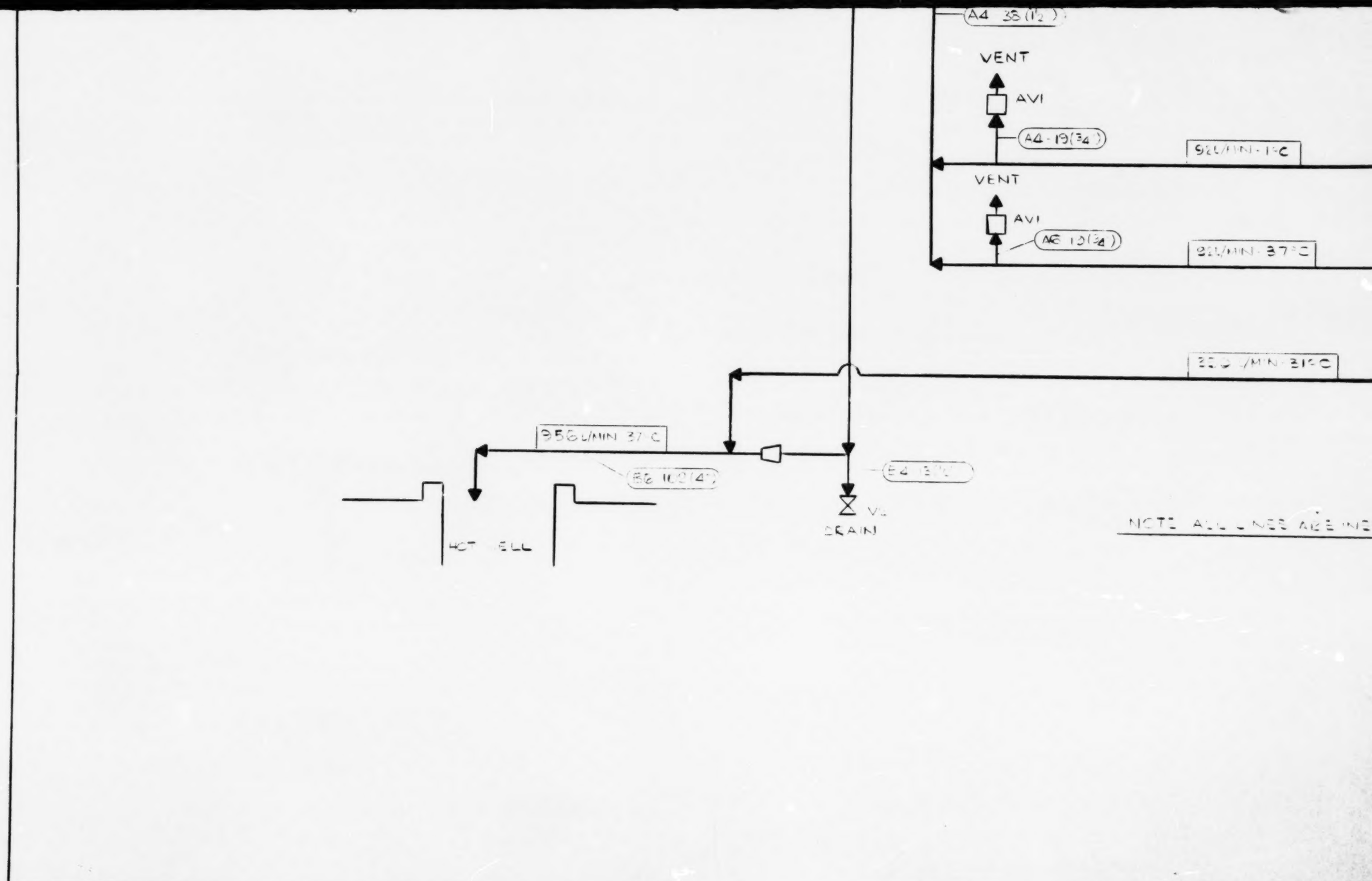
PI1 PI2 PI3 ASHCROFT PRESSURE GAUGE LIQUID TYPE MODEL 25 1002AL CRL RANGE 0-100 PSI
FS1 FS2 3" ITT GRINNELL MC DONNELL NO FS4-3
FS3 ½ ITT GRINNELL MC DONNELL NO FS4-3
FM1 FM2 FM4 2" NEPTUNE GREEN SEAL METER WITH MODEL 157 REGISTER
FM3 1½" NEPTUNE GREEN SEAL METER WITH MODEL 157 REGISTER
TC1-TC2 INCL THERMO-ELECTRIC THERMOCOUPLE CAT # 11434-P-J-4½-14-S

DESCRIPTION	NO.	DATE	BY
SYSTEM UPDATED	3	DEC 82	KGL
INSTRUMENTATION UPDATED	2	AUG 82	KGL
SYSTEM UPDATED	1	JULY, 82	KGL
FOR APPROVAL	0	JUNE 82	KGL

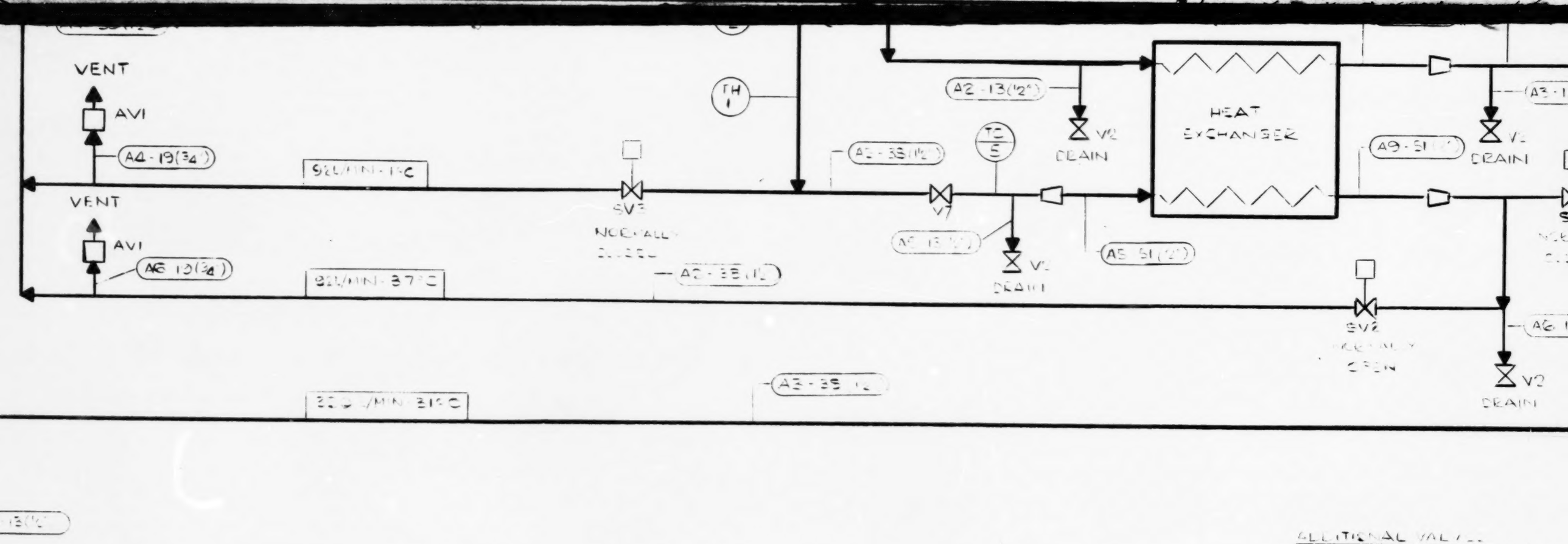
REVISIONS TO DRAWING

ALL PREVIOUS ISSUES OF THIS DRAWING ARE SUPERSEDED

DESIGNED | DRAWN



18 17 16 15 14 13 12 11 10



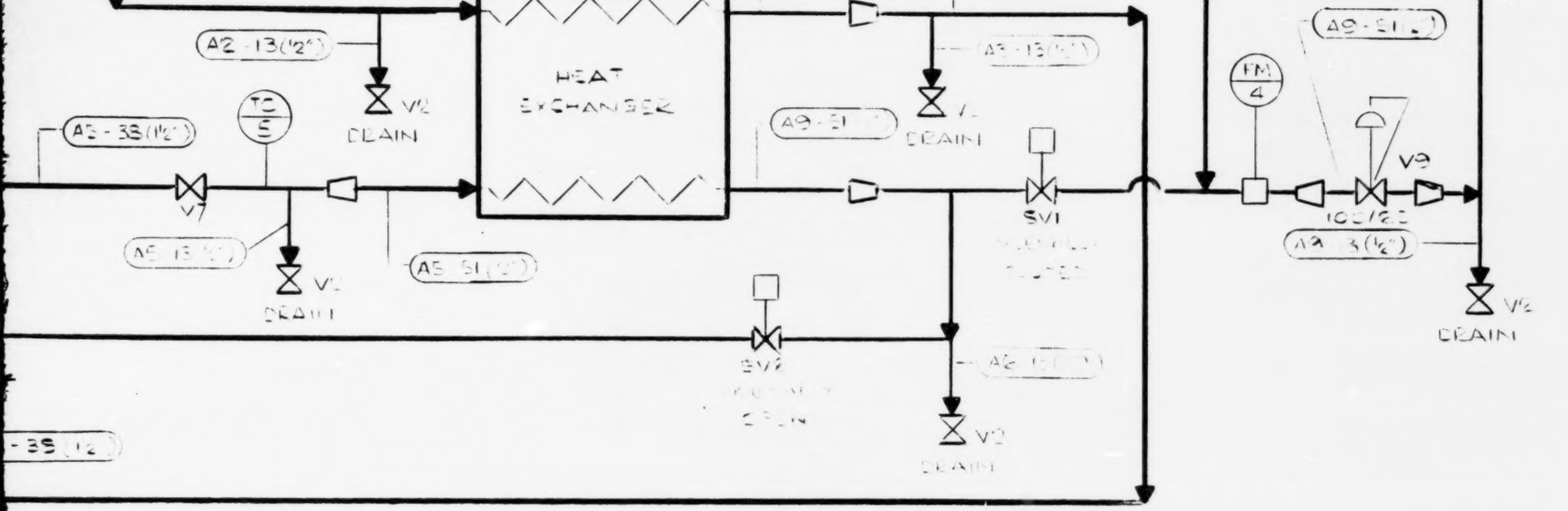
NOTE: ALL LINES ARE INSULATED WITH 2 THICK FIBRE GLASS WITH ELECTRICAL TRACING

ADDITIONAL VALVES

V8 1" CRANE 438 BRONZE GAT

V9 2" CORBAN PRESSURE REDU
SERIES 30 RANGE 30-60
RATING 2 VOLTS SERIN SET
2 1/2

CV1 1" CRANE 37 BRONZE SWING
VALVE



ASS WITH ELECTRICAL TRACING

ADDITIONAL VALVES

V8 [illegible]

V9 [illegible]

SV1 [illegible]

ADDITIONAL INSTRUMENTS

TH1 [illegible]

WITH MODEL 57 REGISTER TO [illegible] INCL THERMO-ELECTRIC THERMO [illegible]			
SYSTEM UPDATED	3	DEC 82	KGL
INSTRUMENTATION UPDATED	2	AUG 82	KGL
SYSTEM UPDATED	1	JULY 82	KGL
FOR APPROVAL	0	JUNE 82	KGL
DESCRIPTION	NO.	DATE	BY

REVISIONS TO DRAWING

ALL PREVIOUS ISSUES OF THIS DRAWING ARE SUPERSEDED

DESIGNED KGL	DRAWN KGL
CHECKED	APPROVED
DATE JUNE 82	SCALE NTS
PROJECT	SHEET OF

BRUNSWICK MINING AND SMELTING CORP. LTD.
SMELTING DIVISION
BELLEDUNE N.B.

PROJECT TITLE

HEAT PUMP INSTALLATION

DRAWING TITLE

P & I DIAGRAM

DWG. NO. 8002-60-0003

REV. NO. 3